VOLUME XXXIII NUMBER 6

BOTANICAL GAZETTE

JUNE, 1902

PHYSIOLOGICAL OBSERVATIONS ON THE SUBTERRANEAN ORGANS OF SOME CALIFORNIAN LILIACEAE.

A. RIMBACH.

(WITH PLATE XIV)

DURING my stay in the neighborhood of the Bay of San Francisco I have endeavored to get acquainted with the life-history of some of the numerous species of Liliaceae growing wild in that region, and my attention has been drawn especially to the physiological behavior of their subterranean organs. As the plants concerned exhibit some quite remarkable features, and have been little studied in this respect, and as they include some species of rather limited geographical distribution, I will give in the following pages an account of my investigations.

CLINTONIA ANDREWSIANA Torr.

The seeds of *Clintonia Andrewsiana* germinate in March. The cotyledon, after having absorbed the contents of the endosperm, serves as the first green leaf, growing 10 ^{cm} long and 3 ^{mm} wide. The primary root, 1 ^{mm} thick, reaches over 10 ^{cm} in length, and forms a few branches of the 1st degree. Its central cylinder is 3-archic, the endodermis with slightly thickened walls, the cortex starch-bearing. There are no signs of contraction. The stem develops into a rhizome, which grows almost vertically downwards to a depth of about 8 ^{cm}, where it passes over into the horizontal direction. Its annual prolongation is in young

specimens 1 to 3 mm, in adult ones 5 to 15 mm. Every year's formation may live over 20 years, so that the rhizome may attain a length of 15 cm and more. At first it forms yearly but one leaf; afterwards a stem 5 cm high with two leaves; finally a stem 12 cm high, crowned with about six leaves, and prolonged into the inflorescence. The leaves last very long, appearing above the ground in February and remaining green until October or November. The youngest portion of the rhizome develops every year, from October until April, the new roots being one or two in young, four to six in full-grown specimens. Their direction is downwards or sidewards. They are uniform throughout, without contraction, branch sparingly in the 1st degree, and are covered with root hairs. In adult specimens they are 2 mm thick, over 20 cm in length, and last about fifteen years. The central cylinder is 12-archic, its innermost part made up of thick-walled cells. The endodermis exhibits strong V-thickenings and thin-walled passage-cells in front of the hadrome rays, and there are no foldings on its longitudinal walls. The moderately abundant cortex is starch-bearing.

In Clintonia the roots are storing organs, but the rhizome is also rather rich in starch-bearing parenchyma. The roots have no influence upon the position of the rhizome. This latter grows downwards or upwards according to circumstances, and is sometimes very much curved.

Prosartes Hookeri Torr.

I found the seedlings of *Prosartes Hookeri* in the middle of April in an advanced state, yet still in connection with the seed. The germination probably takes place in March. The cotyledon, about 10 mm long, remains underground with its tip within the seed. The primary root, 0.75 to 1 mm thick, reaches over 10 cm in length, is uniform throughout, and branches in the first year sparingly in the 1st degree. It is provided with long root hairs. Its central cylinder is 9-archic, and the endodermis has slightly thickened walls. The cortical parenchyma is abundant and full of starch, and there is no contraction.

Immediately after germination the first aerial stem appears,

5–12 cm high, bearing two foliage leaves. There takes place the formation of a rhizome, which grows downwards, and elongates every year, at first 1 to 2 mm, later 3–5 mm, in adult specimens 5 to 15 mm. In old individuals it acquires a considerable length, comprising the formations of many years.

The head of the full grown rhizome produces yearly about five roots. These are 1 to 2 mm thick, over 20 cm long, uniform in all their length, or even increasing a little in diameter at some distance from the base. They run downwards and sidewards, wind very much from the start, and branch sparingly in the 1st degree. Their central cylinder is usually 18-archic, and made up in its innermost part of strongly thickened, very narrow cells. The endodermis has very strong, yellowish V-thickenings, and the adjacent two or three layers of the cortex are also somewhat thick-walled. The cortical parenchyma is abundant and contains starch. The epidermis forms long root hairs. Endodermis and hypodermis do not show any folding of their membranes. There is not the slightest indication of shortening of the root.

The rhizome of Prosartes is often very crooked. It may grow vertically upwards or downwards, according to circumstances. The roots have no influence upon its location.

Prosartes Menziesii Don. behaves just like *P. Hookeri*.

Fritillaria lanceolata Pursh.

The peculiarly shaped rhizome of *Fritillaria lanceolata* does not penetrate to a great depth. Its direction of growth is in young specimens sometimes inclined, in full-grown ones, situated 4 to 6 cm below the ground, horizontal. The yearly advance of the rhizome in horizontal direction amounts to 5 or 8 mm. Every new formation lasts but one year. There is a profuse vegetative multiplication, as larger specimens produce from 30 to 60 lateral bulblets. The plant brings forth yearly in younger specimens three or four, in adult ones about twenty thread-like roots, 0.5 to 1 mm thick and almost 10 cm long, branching in the 1st degree. The roots originate all at once, from one point, and run immediately in a horizontal direction. They have a

3-archic central cylinder and a thin-walled endodermis; both endodermis and hypodermis are without foldings. The roots are purely nutritive.

LILIUM PARDALINUM Kellogg.

In the gulches round Mount Tamalpais, where *Lilium pardalinum* grows in moist, shady places, I found the seedlings in an advanced state, but still connected with the seed, in the middle of April. The cotyledon, 5 mm long, remains underground, and its tip does not abandon the seed. Immediately after germination, however, a foliage leaf 4 cm high is formed. The primary root is 0.5 mm in diameter, furnished with hairs. Its central cylinder is 2-archic, the endodermis cells slightly thickened. The cortex is thin, and no signs of contraction are present.

The shoot develops into a bulb, the axis of which takes up a horizontal direction. The young plant produces every year but one foliage leaf and one to four fleshy scales; also the fleshy base of the foliage leaf, after withering of the blade, remains alive, functioning like a bulb-scale. In such specimens the bulb axis is about 3 mm long, and comprises but one year's product. It produces in the first periods two to four, later four to eight roots, originating exclusively from the lower side. Most of these roots are swollen at the base to 2 mm diameter, and shorten in this portion, so as to become wrinkled on the surface to an extent of 10 or 15 mm. As these contractile roots start from one point and grow almost vertically downwards, spreading away only by their ends, and as the bulb in the young individuals is very narrow, the latter is buried easily in the earth. Hence we find, while the seedlings are scarcely 1 cm below the ground, that half-grown specimens are 5 or 6 cm, full-grown ones 8 to 11 cm in depth.

At the time when the first aerial stem is brought forth the bulb axis is about 5 mm long, and produces about ten scales yearly. For full-grown individuals the annual prolongation amounts to 1 to 3 cm, and as a rule is horizontally directed. In this latter stage of development every year's formation lasts five

to seven years, and thus an old rhizome acquires a length of about 12 cm. Upon its upper side the rhizome bears the scars of the vanished aerial stems, each surrounded by a large number of bulb scales; at its basal end it is separated by a smooth scar from the dead portion. On its lower side the roots are found, five to twelve to each year's formation, starting rather close to each other. They are over 15 cm long, in their basal portion swollen to 3 mm in diameter, and branch rarely in the 1st, very rarely in the 2d degree. They live about five years, and grow from the beginning almost vertically downwards, but soon change their course into the horizontal direction. The swollen part is contractile, and becomes wrinkled to a length of from 5 to 20 mm. The central cylinder is 10-archic, the endodermis furnished with yellowish O-thickenings. In the active cortical parenchyma the cells of the innermost layers are radially elongated, those of the outer strata collapsed and compressed. Both endodermis and hypodermis show the radial longitudinal walls undulated. The epidermis bears root hairs.

In the thin, non-contractile end-portion, which otherwise has the same structure, the undulation of endodermis and hypodermis, the radial elongation of the cortex-cells, and the compressed cell-layers are wanting.

In the adult specimens, which have an ample growth of the horizontal rhizome and branch quite often, the roots apparently have no longer any considerable influence upon the position of the plant. I never found the position of the older parts disturbed. Specimens buried to an excessive depth are found sometimes growing up vertically and forming quite thin, smooth roots.

Scoliopus Bigelovii Torr.

Scoliopus Bigelovii grows in the shade of the redwoods, in moist, cool places. As is known, it flowers early in the year; in 1901 I found the last flowers at Mount Tamalpais at the end of February. By the prolongation and curvature of the stalks the ripening fruits are brought close to the soil, and there they open. I saw the first open fruits at the end of April. In many

instances I found seedlings and young individuals of different ages in dense patches at a distance of at most 30 cm from isolated mother plants. Owing to the length of the stalk the fruit can reach at most the distance of 15 cm from the center of the plant. There does not seem to exist any arrangement for the spreading of the seeds.

The seeds were found germinating in February. The cotyledon remains with its tips for some time in the seed, while its middle portion breaks above the ground by a knee-like curvature (*fig. 1*). Then it leaves the seed and stretches out, being the first green leaf of the plant. The primary root, 1 mm thick and beset with long hairs, reaches only 3 cm in length and does not branch. It has the central cylinder 2-archic, and a thick cortex. The latter becomes filled with starch-grains, except in the basal portion, where starch is almost absent; but here the undulation of the endodermis points to a slight contraction. After germination the diminutive stem of the seedling is at most 2 cm below the ground.

While the cotyledon dies down in the first summer, primary root and stem persist several years, the latter developing into a rhizome, the annual growth of which amounts at first to about 1 mm only. I do not know what the tendency of the rhizome may be regarding its direction of growth. The fact is, that the rhizome, in young specimens of normal, superficial location, assumes an almost vertically downward direction, with the growing point at the lower end (*fig. 2*). But this position, to a great degree if not exclusively, is due to the action of the roots. For the later roots, sometimes even the second one, shorten considerably, and as they all point more or less steeply downwards, they exert a pull upon the rhizome and drag it gradually deeper into the soil. However, as each root contracts only during the first months of its development, the older roots are out of action, and the pull is brought about only by the youngest ones, which arise from the growing end of the rhizome. This circumstance explains also the phenomenon that, while the youngest roots are quite straight, the inactive ones are (the older the more) curved

and bent down in their basal portions, apparently dragged by the movement of the rhizome to which they are attached (*fig. 2*).

The rhizome of old specimens is 3 to 5 cm long, comprising the products of twenty to thirty years, and is found at a depth of 5 to 7 cm. Here it has a horizontal direction, with an annual prolongation of 1 to 3 mm. It branches but rarely.

Young plants, which develop yearly only one leaf, form only one or two roots, while full grown specimens, as a rule, form three each year. The roots break forth all at once, in January or February. They may live twenty years, and therefore there are found sometimes forty to fifty of them on one plant. In older specimens the roots reach 20 cm in length, branch in their end-portion rarely in the 1st degree, and bear numerous root hairs. They are between 2 and 3 mm thick, their basal part, when quite young, being somewhat swollen to 3 or 4 mm. Central cylinder and cortex retain the same proportion throughout the root. The cylinder is mostly 8-archic, the rays being reduced somewhat in number towards the tips. The branches are 4-archic. The endodermis is made up of narrow cells with O-thickenings and thin-walled passage-cells in front of the hadrome-rays. The cortical parenchyma is abundant and the hypodermis very distinct.

This being the general structure of the fully developed root, there are to be noted some differences between the basal portion and the more terminal one, which are related to the functions of these parts.

As already stated, each section of the basal region, soon after having finished its growth in length, begins to shorten. During this process, the active cells of the cortical parenchyma change their form, growing not only shorter, but also broader and becoming radially elongated. In this contraction and change of form, the epidermis, hypodermis, and two layers of cells bordering upon the latter — a complex, which we may designate as *passive outer cortex* — do not join. The outermost layers of the active cortex after a time collapse, are compressed by the expanding inner ones, and form a gradually broadening

zone immediately inside of the passive outer cortex. None of these changes appear in the terminal portion of the root.

Besides, there exists another difference, noticeable even in the primary root, but more pronounced in older plants. In that portion where the cells do not undergo any considerable change of form and size, the cortical parenchyma is densely filled with starch grains; but in the basal region, as far as the parenchyma exhibits strong activity of contraction, starch grains are entirely absent.

The contraction of the cortical parenchyma causes changes also in the passive tissues, inside as well as outside of it. Inside it leaves very characteristic traces in the endodermis. This tissue behaves like the elements of the central cylinder, becoming passively contracted in longitudinal direction. In the beginning, the cell-walls of the endodermis are straight and show nothing exceptional in their outer form, and so they remain in the end-portion of the root and in the branches throughout life. But in the basal portion, as far as contraction occurs, the radial-longitudinal walls of the endodermis become marked by an undulation running longitudinally. This undulation, here as in other species, corresponds to the dark spot, which is observed on the same wall on the cross-section. The undulation or wavy folding of the membrane is most pronounced near the root-base, where the strongest shortening takes place, and diminishes toward the root-end, being entirely absent near the tip.

Quite a similar phenomenon is to be noticed, outside of the active cortex, in the hypodermis. Also in this tissue, the membranes of which are quite straight at the beginning, as far as contraction reaches, an undulation of the radial-longitudinal cell-walls makes its appearance, becoming strongest in the basal region and diminishing and disappearing in the end-portion. The undulation of the cell-wall in both endodermis and hypodermis becomes fixed and remains nearly unaltered by separating these tissues in old roots from the adhering active parenchyma.

Some time after the appearance of the undulation, the pass-

ive outer cortex in its totality, in consequence of the shortening, loses its light connection with the active tissue beneath, becoming separated from it by the formation of the zone of compressed cells already mentioned. Hereupon the root-surface, tight and smooth at the beginning, becomes slack, rough, and wrinkled, and the whole root diminishes somewhat in thickness. The wrinkles begin to show themselves in March, when the roots are 6 to 10^{cm} long, still growing and without ramification. This wrinkled region, very insignificant in the first roots of the young plant, acquires in older specimens a length of about 2^{cm}.

Trillium ovatum Pursh.

Trillium ovatum lives in the same localities as Scoliopus, and also in its manner of life resembles this species in many respects. A difference of organization between both, noticeable even in the seedling, is that in Trillium the rhizome is used in a higher and the roots in a less degree as storing-organs than in Scoliopus.

I saw the germination already finished at the beginning of April. Seedlings and young plants of different age were found very often in the immediate neighborhood of the mother plant. While the cotyledon functions as the first foliage leaf, the stem of the seedling swells up to form a small tuber full of starch. The primary root, nearly 1^{mm} thick, reaching about 8^{cm} in length and forming a very few branches, contains but a small amount of starch grains, its central cylinder is 3-archic, the endodermis furnished with slight thickenings, remaining there as thin-walled passage-cells in front of the hadrome, the cortical parenchyma abundant, the hypodermis very distinct. There are signs of a feeble contraction in the root-base. Primary stem and root persist several years.

The second root, which in the following year breaks from the upper part of the tuber and grows vertically downwards, is considerably larger than the first one, has a thickened basal region, and exhibits there strong contraction, becoming finally wrinkled on the surface to an extent of 10 or 15^{mm}. In consequence of its

shortening it pulls down the tuber into a horizontal position, carrying with it also the basal part of the primary root.

The annual prolongation of the tuber amounts only to 1^{mm}, even in old specimens, but every year's addition broadens it, until in old tubers it comes to a permanent diameter of 10 to 15^{mm}. Such tubers are 3 to 4^{cm} long, containing the living products of twenty to forty years, and die off by degrees at the basal-end with a smooth scar. They do not branch. The full grown tuber brings forth on its lower side yearly two to four roots, situated close together and directed vertically downwards. The roots are about 30^{cm} long and 3 to 4^{mm} thick at the base, taper toward the tip, and branch there very sparingly in the 1st degree. They last about ten years, and twenty or more of them may be found attached to one tuber.

The central cylinder is 6-archic, the narrow-celled endodermis furnished with slight O-thickenings. The rather abundant cortex is almost devoid of starch grains in the swollen basal portion, but contains rather abundant starch in the thin terminal portion. The latter part of the root does not show anything extraordinary. The basal region, on the contrary, shortens very much, the active cortex cells elongating radially. As a result of the contraction, the radial-longitudinal walls of the endodermis become strongly undulated, a zone of compressed cells is formed below the outer cortex, and the root surface becomes wrinkled for a length of 3 to 5^{cm}.

The total shortening of the root probably amounts to about 10^{mm}. The main contraction goes on during the first months of the life of each root. Hence in Trillium, like in Scoliopus, mainly the youngest roots, situated nearest the growing end of the tuber, exsert a pull upon the latter. This pull brings it into an oblique, often vertical position, with the growing point at the lower end, so that the leaf stalk or the aerial stem forms a sharp angle with the rhizome. In this respect young specimens of Trillium and Scoliopus exhibit quite a similar appearance.

By degrees the roots drag down the tuber from the surface into the earth, so that old tubers are usually found 8 to 10^{cm}

below the surface. These latter, as a rule, are no longer inclined, but horizontal. I found here and there, however, always at a considerable depth, old tubers growing vertically upwards, with the roots starting equally from all sides. I am not quite sure about the conditions which provoke this kind of growth, nor about the tendency in the direction of growth the tuber may have in the other cases.

Zygadenus Fremonti Torr.

Zygadenus Fremonti inhabits sunny, dry localities among shrubs, being very frequent in the chaparral. I found the young seedlings in great numbers in January (*fig. 3*). The cotyledon is subterranean; its tip, which is a well separated, roller-shaped sucker 3 to 4^{mm} long, remains within the seed; its lower part elongates downwards, burying the small stem 5 or 10^{mm} into the ground. A linear, upright foliage leaf, 5 to 10^{cm} long, is at once developed. The primary root grows about 6^{cm} long, and is remarkable for its swollen basal part, which is about 1.5^{mm} in diameter. Its central cylinder is 4-archic, the cortex extremely thick. The swollen part contracts a good deal, and thereby buries the stem still more into the earth. At the end of the shortening, we find the endodermis undulated, the active cortical cells radially expanded, a narrow ring of compressed cells formed in their circumference, and the passive outer cortex wrinkled to a length of 15^{mm}. The primary root branches but sparingly in the 1st degree, and is the only one formed in the first year. It dies off in the early part of May.

The shoot of the plant develops into a bulb and produces every year in younger specimens two to four, in the adult ones 10 to 15 roots. The roots originate at the beginning of the rainy season, in December or January, and die off at the beginning of the dry season; hence from June to November the bulb is rootless. They are all contractile, although in a different degree, and send out from the terminal region branches of the 1st and 2d order. In young specimens they always originate from one side of the bulb, so as to bring, by their

one-sided pull, the bulb-axis into an oblique position. In half grown specimens the roots acquire their greatest diameter, about 6^{mm}, and probably also the greatest amount of shortening, and drag the bulb every year 1 to 2^{cm} downwards (*fig. 4*). Their course is very characteristic, the contractile basal portion pointing almost vertically downwards, the inactive terminal portion passing into the horizontal direction. The central cylinder in these roots is usually 8-archic. In full-grown, old specimens, the growing point of which, as a result of the dragging of the roots, lies at a depth of 10 to 12^{cm}, the roots are thinner, at most 3^{mm} in diameter, start equally from all sides of the bulb-axis, and run in a flatter course (*fig. 5*). Their central cylinder has on an average nine rays, that of the branches three rays. In April, when the contraction is ended, the endodermis is furnished with exceedingly strong O-thickenings of yellow color, the hollow of the cells sometimes almost being filled up; but thin-walled passage-cells are present in front of the hadrome-rays. The cortex is copious. Root hairs are numerous. The bulb keeps, as a rule, a vertical position, elongates from 3 to 5^{mm} every year, and comprises the products of two years.

Remarkable are the differences between the contractile basal portion and non-contractile terminal portion of the root. For instance, the central cylinder preserves its diameter throughout its whole length, only the number of rays diminishing very little toward the tip; the cortex, on the contrary, is twice as thick in the basal region as in the terminal. Furthermore, the radial-longitudinal walls of the endodermis acquire, in consequence of the shortening, a strong undulation in the basal part of the root (*fig. 6*), whereas in the terminal part they do not show this peculiarity (*fig. 7*). Finally, the endodermis remains in the basal region thin-walled, until the contraction is finished, while in the non-contractile terminal region the thickenings make their appearance before that time.

Chlorogalum Pomeridianum Kunth.

Chlorogalum pomeridianum grows in dry, open localities, preferring rocky hills. In its manner of life it shows much resem-

blance to Zygadenus. Like the aerial organs, the roots also last only one vegetative period, sprouting at the beginning of the rains, in December and January, and dying off at the beginning of dryness in June or July.

Young seedlings were found in the latter part of January (*fig. 8*). The cotyledon is subterranean; its upper end, a globoid sucker, about 4^{mm} wide, remains in the seed, the rest elongates about 10^{mm} downwards, carrying the stem as far into ground. At the same time the first foliage leaf is sent forth, about 7^{cm} long with a blade 4^{mm} wide. The primary root, 1^{mm} thick and 5^{cm} long, develops near its end a few branches. Its central cylinder is 3-archic, the cortex moderately abundant. Its basal portion shortens, and in the thin walls of endodermis and hypodermis appears a heavy undulation. Besides the primary root, during the first year one or more roots appear, longer and gradually thicker, but in form and function equal to the first one.

From the second year onward a difference shows itself in the formation of these organs. At first from two to eight thin, thread-like, non-contractile roots are formed. They are 0.5 to 1^{mm} thick, have a 4- or 5-archic central cylinder, and a moderately abundant cortex. After these, one or more roots appear, similar to those of the seedling, very thick in the basal region and tapering towards the tip, strongly contractile and growing vertically downwards (*fig. 9*). The largest of these I found were 10^{mm} in diameter, and were thicker than the bulb from which they arose. In these the central cylinder is 9–12-archic, the endodermis thin-walled, the cortex enormously abundant. The latter shows the radial elongation of the cells and a wide zone of compressed tissue (*fig. 11*). Both kinds of roots branch for a time in the 1st and 2d degree.

The work of the contractile roots is considerable. The downward movement of the bulb was in several specimens 1.5^{cm} during one vegetative period. In this movement the bulb carries with itself the thread-like roots of the present year and also the dead but still adhering roots of the preceding year (*fig. 9*).

Thus, the growing point of the bulb, lying in the seedling 1 or 2 cm below the surface of the earth, is brought finally to the depth of 10 to 15 cm. There it is met, as a rule, in the full grown specimens, in which the bulb has attained a large size (*fig. 10*). An adult specimen produces about seven roots each year. Among these the difference in form and function disappears; they are all of the same kind, about 5 mm thick, tapering soon to 3 or 2 mm in diameter, and take up not a vertical, but more oblique course from the start. They are very long, covered with hairs, and form later on branches of the 1st and 2d degree. Their central cylinder is usually 13-archic, but the cortex reduced in abundance compared with that of the napiform roots of the half-grown specimens. The annual prolongation of the bulb-axis amounts in these old plants to 5 to 8 mm. So much are they carried down by the roots, however, that a full grown bulb, very superficially located, moved down in one year 2.5 cm.

In connection with the study of Chloragalum I should like to emphasize some facts concerning the behavior of the contractile roots. In Chloragalum, as in other species, the contraction does not appear in the whole root at once. On the contrary, as each section of the root a short time after having finished its growth in length begins to shorten, necessarily the older basal sections commence their contraction earlier than the younger, more terminal ones; also the phenomena accompanying the contraction appear sooner in the base. Thus we see in the napiform roots of Chloragalum that after a time the bark, smooth and light at first, becomes slack and wrinkled at the base, diminishing also in diameter, and that by degrees this wrinkling and falling down advances toward the tip over all the swollen basal region (*fig. 9*).

The roots of Chloragalum do not wait to commence their contraction until they have attained their entire length, nor do those of Zygadenus, Trillium, Lilium, Scoliopus, Arisaema, nor any other species I know of. On the contrary, in all these the contraction sets in when the roots are quite short, a few centimeters in length.

Neither do the roots of our plant wait to contract until they

have anchored themselves by lateral rootlets. On the contrary, when the few branches are formed, the contraction of the root is nearly or entirely finished. The same is true for the described species of Zygadenus, Trillium, Scoliopus, and likewise for *Calochortus umbellatus*, *Brodiaea capitata*, *Arisaema Dracontium*, and others. There are even contractile roots of a very strong dragging effect, which do not branch at all, as is the case in *Arum maculatum* and *Fritillaria Meleagris*. Apparently the close adherence of the root surface with the earth gives a sufficient support, and it seems even that in certain cases the presence of root hairs is not necessary for bringing about the effect.[1]

Calochortus umbellatus Wood.

The bulb of *Calochortus umbellatus* is brought from the surface of the earth, where the seed germinates, to a considerable depth exclusively by the action of contractile roots. The bulb axis always grows vertically upwards, but not more than 1 or 2 ^{mm} a year, even in full grown specimens, in which the bulb is about 2 ^{cm} high and 1 ^{cm} thick. The whole plant renews itself annually, every part of it lasting but one cycle of vegetation.

At the beginning of the rainy season the bulb produces ten to twenty thread-like roots, 0.5 to 1 ^{mm} thick and 10 ^{cm} long, which give off numerous branches of the 1st and 2d degree. Those roots have the central cylinder 3-archic, a thin-walled endodermis, a moderately abundant cortex, endodermis and hypodermis straight-walled; they do not contract and are merely nutritive (*fig. 13 r*).

After these there appears one large napiform, contractile root (*fig. 13 r*[1].) It is in the basal portion from 2 to 4 ^{mm} thick, but is attenuated near the end to 0.5 ^{mm}. The central cylinder is 15-archic, and the cortical parenchyma copious. The active cortex cells elongate radially, their outermost layers collapse, and form a ring of compressed tissue bordering upon the passive outer cortex. The radial-longitudinal membranes of the thin-

[1] In regard to these details the descriptions of the phenomena concerned, as given in Kerner's *Plant Life* 2: 769. 1891, and in MacMillan's *Minnesota Plant Life*, pp. 218, 219, 1899, are not exact.

walled endodermis become strongly undulated. After conclusion of the shortening, in April, this root ramifies sparingly. In larger specimens the root drags down the bulb 10 to 15 mm. By this movement the thread-like roots become displaced very much, and the bulb itself pulled out of the old husk, which sticks to the earth and remains in its place. The husks of several years sometimes persist, indicating the amount of work done by the roots in the respective periods (*fig. 13, h*).

Arriving at a depth of 6 or 7 cm, the plant stops the formation of contractile roots, producing then exclusively thread-like ones. In this state the new-formed bulb remains within the old husk, and at its bottom the remnants of the bygone bulb-axis accumulate, piled upon each other.

Brodiaea capitata Benth.

In full grown specimens of *Brodiaea capitata*, a species growing on sunny meadows, the subterranean part of the shoot is a tuber of vertical growth, rich in starch, about 15 mm thick, roundish, bearing on its lower end a round scar, the place where it was united with its predecessor. Its position is very superficial, only 3 to 5 cm below the ground.

It lasts but one year. In January, after starting the leaves, it begins to shrink and to become empty, but forms on its upper end a superposed new tuber. At the same time, from the base of the latter two pairs of lateral buds grow out, which likewise develop into small tubers, being supported by thin stalks about 1 cm in length (*fig. 14*). Each of these four lateral tubers is ensheathed by a fleshy sheathing scale, which later on dries up and becomes a brown husk. The stalks also die down, so that at the end of the rainy season the four small tubers are free, although still quite close to the mother plant.

The following year, at the beginning of the rains, mother and daughter tubers develop leaves and roots (*fig. 15*). The main tuber puts forth thirty to forty thin roots in a nearly horizontal direction, which become 10 cm long and sparingly branch. They have a 4-archic central cylinder with central vessel, endo-

dermis with feeble V-thickenings, and a narrow cortex. They show nothing peculiar, and are purely nutritive.

The daughter tubers, however, behave differently. After having formed two or three thin roots of the structure of those just mentioned, each of them sends out one thick, fleshy, contractile root (*fig. 15, r*[1]). This root grows in a strictly horizontal direction, keeping in its whole extent not far from the surface of the soil. It reaches over 20[cm] in length and 3 to 4[mm] in diameter, tapering in its terminal portion to 1[mm] in thickness. Its central cylinder is 5-archic with a central vessel, and the cortex is very thick.

It is semi-transparent, and it can be seen that the course of the central strand is not straight, but irregularly undulated and spiral (*fig. 16*). Such a course of the central strand is very uncommon in monocotyledons. Also in this case it seems to be not so much a necessary consequence of the shortening itself, as a consequence of the irregular manner in which the active cortical cells change their form. While in other roots the cortex behaves equally all around the central cylinder, in this case the radial elongation of the cells seems to take place now on one, now on the other side of the root, and the volume of the cortex increases alternately on different sides of the strand. This strange phenomenon, and the manner in which it is brought about, deserves a closer investigation. In consequence of the contraction the membranes of the thin-walled endodermis, as well as of the hypodermis, become undulated, and the root surface wrinkled to an extent of 3[cm] from the base. No zone of collapsed cortical cells, however, forms. The anatomical peculiarities mentioned disappear near the tip.

The root seems to shorten about 10 or 20[mm]. From every one of the lateral tubers the contractile root grows toward the outside, turning away from the mother plant. The result of the contraction is that every lateral tuber is pulled out of its husk, which remains on the spot, and is removed horizontally about 10[mm] (*fig. 15, t*[2]). During this process the small tuber, now in a horizontal position, shrivels and forms a new tuber on its top.

In the later part of the rainy season the emptied tuber-portion dies off with all the roots, and the following year the new tuber sends up its leaf about 1^{cm} away from the mother plant. The formation of horizontal contractile roots seems to repeat itself several times in the same individual.

This mode of loosening crowded colonies by the action of horizontal roots occurs, according to Kerner von Marilaun (*Plant Life* 2:769. 1891), also in *Muscari racemosum* and *Ornithogalum nutans*. I have not yet had an opportunity of seeing it in these species. But it is by no means a frequent phenomenon, and does not occur at all in most of the bulbous plants, as Kerner assumes in the quoted passage. From my own experience, contractile roots of strictly horizontal direction seem to be very rare, and therefore their occurrence in Brodiaea is the more noteworthy.

Reviewing the ten species examined, we can state that, although they are geophilous herbs of similar organization, they nevertheless show extremely different modes of burying themselves. From this point of view we may arrange these plants in three groups:

The first group includes Clintonia, Prosartes, and Fritillaria. In these the rhizome alone, by its movement of growth, determines the location of the plant in the earth. It develops horizontally, and is not influenced in a mechanical way by the roots, which are not contractile.

The second group is formed by Lilium, Scoliopus, and Trillium. Here the growth of the horizontally developing rhizome determines in a much smaller degree the location of the plant. In general the influence of the contractile roots prevails in fixing the position of the rhizome.

The third group contains Zygadenus, Chlorogalum, Calochortus, and Brodiaea. In these the rhizome develops vertically, and the contractile roots determine almost exclusively the position of the plant.

Furthermore, we find that in Clintonia, Prosartes, Fritillaria, Lilium, Scoliopus, Trillium, and Zygadenus the roots are all of

the same kind and differ but slightly; whereas in Chlorogalum, Calochortus, and Brodiaea there takes place a division of labor between nutritive and contractile roots, accompanied by a striking difference in form.

Finally, considering the age the roots may attain, we see that it amounts to many years in Clintonia, Prosartes, Scoliopus, and Trillium, and to a few months only in Fritillaria, Zygadenus, Chlorogalum, Calochortus, and Brodiaea. Contractility is found not only in long-lived roots, but also, and in a very high degree, in short-lived ones. Long-lived roots assume also the function of storing reserve material; they may be contractile (Scoliopus, Trillium) or not (Clintonia, Prosartes). In those species which during a certain time of the year are rootless the roots never seem to be used as storing organs.

San Francisco, Cal.

EXPLANATION OF PLATE XIV.

All figures are drawn from nature, and where not otherwise indicated are natural size. The horizontal dotted lines indicate the surface of the earth. All the figures are in the natural position and distance with regard to these lines.

Scoliopus Bigelovii.

Fig. 1. Seedling: *s*, seed; *c*, cotyledon; *r*, root.

Fig. 2. Half-grown, descending specimen, at the end of January: *rh*, rhizome; *r*, fully developed roots of former year; r^1, new developing roots; *st*, aerial stem.

Zygadenus Fremonti.

Fig. 3. Seedling: *s*, seed; *c*, cotyledon; *l*, leaf; *r*, primary root.

Fig. 4. Half-grown, descending specimen, in February: *b*, bulb; *r*, contractile roots of the present year; r^1, remnants of roots of the preceding year, carried down by the movement of the bulb.

Fig. 5. Bulb of full-grown specimen, in March; longitudinal section: *a*, bulb-axis; *st*, aerial stem of the present year; st^1, aerial stem of the preceding year; *r*, contractile roots.

Fig. 6. Endodermis from the basal portion of a contractile root; tangential section. × 200.

Fig. 7. Endodermis from the terminal portion of the same root; tangential section. × 200.

Chlorogalum pomeridianum.

FIG. 8. Seedling: *s*, seed; *c*, cotyledon; *l*, leaf; *r*, primary root; r^1, second root.

FIG. 9. Half grown, descending specimen, in the latter part of January: *b*, bulb; *r*, non-contractile roots; r^1, contractile root of the present year, with the wrinkles appearing at the base; r^2, dead, contractile root of the preceding year, pulled downwards by the movement of the bulb.

FIG. 10. Lower portion of adult bulb; longitudinal section: *a*, bulb axis; *bs*, bulb scales; *st*, aerial stem of the present year; st^1, remnants of the aerial stem of the preceding year; *r*, living root of present year; r^1, dead root of preceding year.

FIG. 11. Cross-section from the basal portion of a contractile root of a young, descending specimen, × 5: *cyl*, central cylinder; *in*, inner (active) cortex; *com*, layer of compressed cells; *out*, outer (passive) cortex.

Calochortus umbellatus.

FIG. 12. Young, descending specimen, in April: *b*, bulb; r^1, contractile root; *h*, husk of the last year.

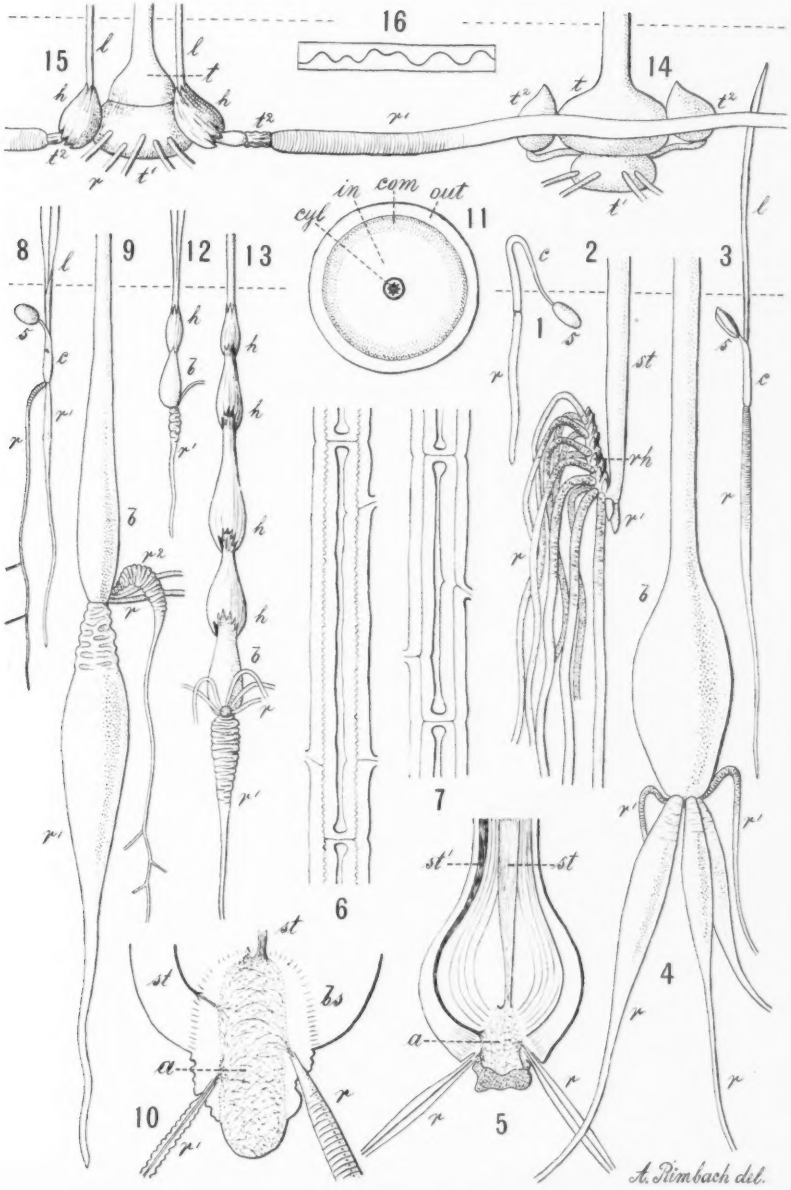
FIG. 13. Almost full grown, descending specimen, in April; the contraction is finished: *b*, bulb; *r*, non-contractile roots; r^1, contractile root; *h*, dead husks of preceding years.

Brodiaea capitata.

FIG. 14. Subterranean parts in March: *t*, newly formed part of main tuber; t^1, old, decaying part of the same; t^2, new, lateral tubers fully developed.

FIG. 15. Subterranean parts in January: *t*, new part of main tuber in formation; t^1, old part of main tuber; t^2, last year's lateral tubers, shriveled and carried away from the mother plant; *h*, dry husks of the same; *l*, leaves of the same; *r*, thin roots of main tuber; r^1, contractile root of lateral tuber.

FIG. 16. Piece of contractile root, showing course of central strand. × 2.



RIMBACH on SUBTERRANEAN ORGANS

THE PARASITISM OF BOTRYTIS CINEREA.

RALPH E. SMITH.

(WITH TWO FIGURES)

THE classic works of De Bary (1), Kissling (3), and Marshall Ward (2) were the first to call attention to a mode of parasitism in fungi which had not previously been recognized. These investigations brought out the fact that in certain fungi parasitism is brought about by the secretion of a soluble substance by the mycelium which kills and disintegrates the host tissue at a considerable distance from the filaments, thus affording them practically saprophytic nourishment. This substance was thought by each of these investigators to be of the nature of a soluble ferment or enzyme, possessing the power of dissolving cellulose, whereby the injurious effect. Without detracting from the value of these investigations, it may be said that from more recent works on the subject it is evident that there is still much to be explained in regard to the phenomena which these earlier writers described.

The fungi to be considered in this connection form a closely related group which may be designated as the Botrytis-Sclerotinia type. *Botrytis cinerea* has been chosen as the subject of the present article, but the related *Sclerotinia Libertiana*, the subject of De Bary's work, as well as other forms of Botrytis of the *cinerea* type, come naturally into consideration.[1]

As a saprophyte no mold is more generally prevalent than *B. cinerea*, but to the pathologist this species is of special interest on account of its peculiar relations to the phenomena both of saprophytism and parasitism. It is, in a general sense, an example of the facultative parasite of Van Tieghem and De Bary, or the hemi-parasite of Von Tubeuf; the term *Gelegenheits Parasit* of the latter writer describes it more accurately. Briefly

[1] See no. 13 in the list of literature as to the genetic relation of these forms.

stated, the usual conditions under which this organism may affect living plants are as follows: excessive moisture, stagnant air (these two especially when combined with high temperature), low vitality of the host plant, and upon young or delicate parts of plants. While not covering all cases, the parasitic attacks of Botrytis may almost always be ascribed to one or a combination of these conditions. (A number of typical cases of Botrytis attacks are described or referred to in the writer's previous article.) All degrees of parasitic activity occur under these favorable conditions, from growth upon ripe fruit, where the fungus is scarcely more than a saprophyte, to vigorous development upon live growing tissue.

Generally stated, this species is disseminated by means of its conidia, which germinate upon parts of plants and send germ tubes into the living tissue, where they spread about, causing death and disintegration. Kissling found that, unless germination started with saprophytic nourishment at hand, no infection took place, a peculiarity previously discovered by De Bary in *Sclerotinia Libertiana*. Potter (**8**) found, however, that living tissue could be affected directly with conidia in water. Marshall Ward also found direct infection possible in the form of Botrytis which he investigated. The variation in this respect expressed by these results has been found by the writer to be a constant one. With some material direct infection could be produced in a moist chamber, while at other times such attempts were unsuccessful. In all cases much more active infection took place when saprophytic nourishment was used as a starter. The conclusion therefore seems justified that Botrytis varies in the ability of its conidia to produce directly parasitic germ tubes, but with a general tendency to require a saprophytic start.

After infection has taken place, the affected tissue becomes softened and dead and rapidly disintegrates. In the case of fleshy substances, such as turnips and carrots, it is noticeable that, as long as no other organisms become abundant, no disagreeable odor whatever is produced, even when the tissue is thoroughly permeated by the fungus. In *fig. 1* is shown the

characteristic effect of Botrytis filaments upon vegetable tissue, as seen under the microscope. Here is represented a filament of Botrytis growing in the petiole of a lettuce leaf, a soft, succulent tissue. The effect is seen to be a darkening in color, loss of turgidity, disintegration of protoplasm, a separation of the cells from one another, and their final collapse, the tissue being affected considerably remote from the filaments. The same effect is seen in the vicinity of a germ tube penetrating the surface. To the naked eye affected tissue is found to be softened and disintegrated, having the appearance of being boiled. From the nature of this effect it is evident that such a fungus as this is not in a strict sense a parasite. That is, it does not live directly upon living tissue as, for example, the Uredineae, but rather subsists strictly upon dead and disintegrated plant substance. Its parasitism consists in its ability, limited to the conditions already enumerated and varying greatly in intensity, to secrete a substance which has a toxic effect upon living tissue. The nature of this substance may now be considered. Marshall Ward brings out the idea that the filaments secrete a cellulose-dissolving enzyme, which attacks the cell walls and transforms their substance into available food material for the fungus. Kissling records the same result. De Bary showed the same to be true in the case of the species which he investigated.

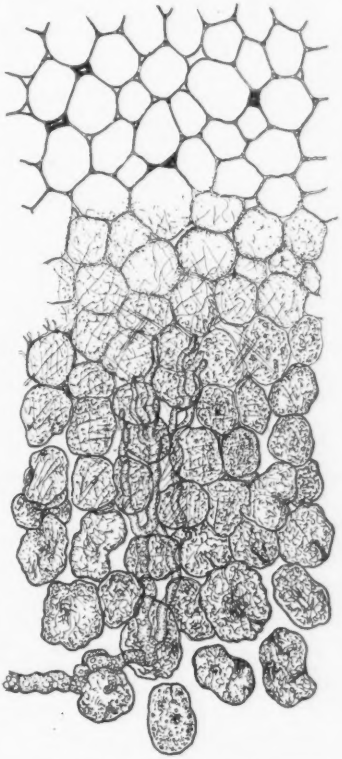


FIG. 1.—Filament of *Botrytis cinerea* invading the tissue of a lettuce petiole.

According to the first author, a watery extract of Botrytis mycelium caused, in thin slices of vegetable tissue, a dissolving of the middle lamellae and strong swelling and final dissolution of the cell walls. When such extract had been previously boiled no effect appeared. No statement is made as to any definite effect upon the cell contents. Kissling also assumes that a cellulose enzyme is the sole cause of the destructive effect. De Bary reaches the same conclusion in regard to *Scl. Libertiana*, but not without some apparent misgivings. At one point (p. 418) he says: "By a single brief boiling the juice [mycelium extract] loses its specific poisonous effect," but again (p. 421) "the difference [between the effects of boiled and unboiled extract] is to be sure a quantitative one so far as can be observed. . . . . With the liquid from sclerotia the same differences appear, though less prominently; the boiled has here a relatively greater effect." Behrens (10) found that boiling an extract of Botrytis mycelium did not destroy its injurious effect upon plant tissue.

It seems reasonable to suppose that a watery extract of the mycelium of this fungus should contain any soluble substances secreted by the filaments, and have the same effect upon tissues, so far as enzymes and any other soluble substances are concerned, as the fungus itself. In preparing such extracts the writer has made use of the following method: Large flasks of any good liquid medium, usually prune juice, were prepared and sterilized, and then inoculated with Botrytis. A vigorous mycelium soon developed upon the surface, which was removed and washed, then cut up into small fragments and finally ground to pulp in a mortar with clean quartz sand. This pulp was then placed in water, and allowed to stand in a warm place for several hours, after which the clearer portion was decanted off, thus getting rid of the sand, and strained. When vegetable tissue was placed in such an extract the effect was very similar to that produced by the growth of the fungus. If a lettuce leaf was placed with the petiole in a flask of the extract all the tissue in contact with the liquid became softened and discolored, and soon

disintegrated, just as in a leaf with the fungus actually growing in the petiole. In a thin section placed in this substance the cells underwent the characteristic changes shown in *fig. 1*, except that more plasmolysis took place. Apparently, therefore, the toxic principle of this fungus is a soluble substance given off by the mycelium.

It was especially noticeable in these tests that the marked swelling of the walls described by Marshall Ward did not occur. No change whatever could be detected in this respect. Behrens and Nordhausen (**12**) also found this to be true with *Botrytis cinerea*, while De Bary's casual mention of a slight swelling can hardly be construed to denote the highly characteristic effect described by Ward. Potter (**9**) found apparently the same effect produced by bacteria. The writer has found no marked change produced by boiling the extract. Certainly the softening of the tissue and death of the cells resulted as before. It is evident, therefore, from the last result alone, that the effects of this fungus upon plant tissue are not entirely due to an enzyme.

The study of the subject has led the writer to the conclusion that two different effects must be clearly distinguished, one following the other: first, the death of the cells; and second, the disintegration of their walls and contents. The further conclusion has been reached that the first effect is produced by a poisonous substance, not an enzyme; the second by a variety of enzymes not necessarily always the same, each affecting its particular substance. The latter conclusion has been deduced from the results of a large number of cultures, made to ascertain the ability of Botrytis to thrive upon various substances of vegetable origin, likely to occur in plants. For this purpose there was first made up a normal mineral-peptone solution, according to one of the usual formulæ, and to portions of this stock solution were added the various substances to be tested, and flask cultures made in the usual manner. These substances may be taken up separately.

Starch.— It was found impossible to grow Botrytis upon this substance, although Behrens states the contrary. In the first

experiments a medium was made up by adding 2^{gm} of commercial cornstarch to each 98^{cc} of the stock solution. The starch did not dissolve to any great extent, but formed a paste. Inoculated with Botrytis only a very feeble growth resulted. From this it seems that this species has not sufficient power of hydrolizing starch into a form of sugar in which it could be assimilated to provide for its full development. It was found, however, that in a very dilute starch solution hydrolysis could be brought about by adding an extract of the Botrytis mycelium, as shown by the iodine test. From this it appears that the fungus secretes at least a small amount of diastase.

Dextrose (glucose, grape sugar).—A 3 per cent. solution of this substance in the stock solution was used as a culture medium. Growth was rapid, and development luxuriant, as was to be expected.

Cane sugar.—A solution containing this substance was made as in the last case. Growth was at first slow, so that at the end of the first week the dextrose cultures were much ahead. Gradually, however, the development became more vigorous, and the final result was as good as any. This course of development gave reason to suppose that it was first necessary to invert the cane sugar before it became available, and that the fungus possessed the power.

Milk sugar (lactose).—The results with this substance were very similar to those with the last; a rather slow start, but eventually a vigorous development.

Maltose.—Vigorous growth from the first.

Levulose (fructose).—Same as last.

Galactose.—Good growth.

Dextrin.—Growth in this substance started rather slowly, but soon became as good as any.

Inulin.—In a 4 per cent. solution of inulin in the stock solution only a very slight growth of Botrytis could be obtained. No normal development whatever took place.

Glycerin.—With 2 per cent. glycerin in the stock solution very good development took place.

Gum arabic.—A similar result to the last was obtained with 4 per cent. gum arabic.

Cellulose.—Cultures were made by using the purest obtainable cellulose, in the form of filter paper, mixed into a pulp with the stock solution. An excellent growth took place in this medium, showing that the fungus was able to utilize cellulose as a food material. Behrens obtained similar results.

Linseed oil.—A 4 per cent. solution of this substance was made in the stock solution. This naturally formed a layer upon the surface, but by frequent shaking the oil was kept mixed with the other liquid for a considerable portion of the time. Growth in such cultures was very good, and a normal development took place. The solution gradually became darker in color until nearly black, while the oil lost its characteristic appearance and the dark colored liquid became homogeneous in appearance.

Cottonseed oil.—Similar results to the last were obtained with this substance.

Tartaric acid.—Two grams of this substance in the dry form were added to 98^{cc} of the stock solution. Growth was excellent throughout.

Malic acid.—With a similar solution of this substance a very vigorous development was obtained.

Oxalic acid.—With this substance in the same proportion no growth whatever appeared.

Formic acid.—To 98^{cc} of the stock solution 2^{cc} of 98 per cent. formic acid was added. No growth appeared.

Tannin.—A 2 per cent. solution of commercial tannin was made with the stock solution. Growth was excellent, the solution slowly turning black.

Asparagin.—With a 1 per cent. solution of this substance in the stock solution, a very quick growth appeared, developing conidia more quickly than in any other culture. Subsequent growth was not very vigorous.

Salicin.—With a 1 per cent. solution of this substance growth was very slow, but in time reached a fairly vigorous development.

Amygdalin.—In a 2 per cent. solution of amygdalin growth was slow and only fair. The odor of almonds became noticeable in the culture after some development had taken place.

Brucin and strychnin.— In 1 per cent. solutions of these poisonous substances growth was extremely feeble and practically nothing.

Quinin and thein.—In 2 per cent. solutions of these substances no growth took place.

It appears, therefore, from the above results that *Botrytis cinerea* is able to satisfy its carbon requirements from the following substances: sugars in general, dextrin, cellulose, glycerin, gum arabic, vegetable oils, tartaric and malic acids, asparagin, and several glucosides, as tannin, salicin, and amygdalin. The effect of the growth of the fungus upon these substances may now be considered. In studying this point the method used was to reserve a portion of each solution tested, which could later be compared with the remainder of the solution, upon which Botrytis had developed.

SUGARS.

No extensive study was made of the complicated transformations of the various sugars which take place under such circumstances as these. The Fehling test showed that in all cases the solution upon which Botrytis had been growing gave a strong reduction, so that in the case of cane sugar inversion had taken place. It was found that oxalic acid was produced in considerable amount from the sugars, presumably by oxidation, and occasionally traces of acetic acid. Alcoholic fermentation was carefully looked for, but no trace of this substance could be detected in the distillate from the culture fluid. The specific effect of the growth of the fungus upon dextrin, cellulose, glycerin, gum arabic, asparagin, and acids, was not studied. The same is true in regard to the vegetable oils, except that the darkening in color and disappearance of the distinct nature of the oil was apparent to ordinary observation, showing that an important change took place.

TANNIN.

The effect of the growth of Botrytis upon commercial tannin was quite closely followed. It has already been mentioned that the liquid gradually became of a darker color and finally nearly black. The same effect could be shown by mixing a 2 per cent. solution of tannin in a flask of gelatine. A flocculent precipitate occurred, giving the hardened gelatine a white color. When inoculated with Botrytis this color began to disappear about the point of inoculation and turn brown. Gradually the change spread, keeping pace with the growth of the organism, until finally the whole mass of gelatine to a considerable depth had this dark color. This is an excellent method for showing this reaction.

A solution of tannin in the stock solution was divided into two portions and one inoculated with Botrytis. After the end of one week the latter was dark brown in color, while the original portion was still nearly colorless as at first. Both gave a deep purple precipitate with ferric chloride. With calcium hydrate the original solution gave a white precipitate, changing to lilac (tannin reaction.) That upon which Botrytis had grown gave a heavy precipitate, the color of which could not be clearly distinguished on account of the dark color of the liquid. Another portion of the Botrytis liquid was agitated with ether, and the ether then poured off and tested with calcium hydrate. This gave a brown precipitate rapidly darkening (gallic acid reaction). A solution of gelatine gave with the original tannin solution a heavy white precipitate. With the culture fluid no precipitate appeared. After adding an excess of gelatine to both solutions they were again tested with ferric chloride. The original liquid gave no reaction, all the tannin having been precipitated. The other still gave the deep lilac reaction. It was therefore shown plainly that the tannin had been decomposed by the fungus, and that gallic acid was one of the products of decomposition. To portions of each liquid calcium hydrate was added till no further precipitate occurred. These were filtered, and portions of the filtrates tested with ferric chloride until solutions were obtained

entirely free from tannin and gallic acid. With the original solution the final filtrate was perfectly clear. The culture liquid still retained its dark color. These filtrates were then tested with Fehling's solution for sugar. The first gave no result. (It was necessary to remove the tannin, as the substance reduces copper.) The culture fluid gave a strong glucose reaction. These results show therefore that Botrytis decomposes commercial tannin into glucose, gallic acid, and a dark coloring matter whose nature was not further investigated.

SALICIN.

The culture fluid containing this substance was tested with ferric chloride for saligenin, which was always found to be present, though in small amounts. It has previously been mentioned that growth upon this substance was very slow. Apparently the usual decomposition of salicin into saligenin and glucose is effected by Botrytis.

AMYGDALIN.

It has been mentioned that after the growth of the fungus upon this substance was under way, an odor of almonds could be easily detected, which was not apparent in the original solution. This indicates the decomposition of amygdalin into glucose and hydrocyanic acid.

It may be assumed in a general way that these changes in the nutrient media are brought about by the corresponding enzymes, which are secreted by the fungus. It has not been considered necessary to the present discussion to attempt to isolate or study these individually, though this organism is well adapted to such a study. The method of treating substances to be tested with an extract of the mycelium is to be used as a basis for such work. (The citations in Green's work, especially those on the work of Bourquelot and his associates, will be found instructive.) The results of the cultures show in general that this fungus is able to avail itself of most of the ordinary constituents of vegetable tissues when unprotected by vital activity.

The cellulose enzyme calls for especial mention on account of the prominence which has been given to it. It appears to the writer that the discrepancy between the results of Marshall Ward and those of Behrens; Nordhausen, and himself in this respect is to be explained by the varying composition of the substance broadly called cellulose, and the varying ability of fungi to dissolve this substance. In all cases it appears that the more easily affected forms, the hemi-celluloses and pektoses, forming the middle lamellae, etc., were dissolved. That the fungus studied by the writer is able to affect, to some extent, true cellulose, is evident from the cultures on filter paper; but in the case described by Ward, and also that by Potter, where a strong swelling of the cell wall was produced, the most rational explanation seems to be that an entirely different enzyme was present. (See Newcombe (**11**) and Green (**14**), p. 84, on the general subject of cellulose enzymes.) But, however this may be, the point seems clear that the cellulose enzyme or enzymes are subordinate in effect to some toxic substance of a different nature. The effect of the boiled mycelium extract, plasmolyzing and killing the cells with which it comes into contact, is enough to show this. Furthermore, the cellulose enzyme idea of Ward and Kissling allows no explanation of the first entrance of the germ tube through the cuticle. The former says (p. 354) "the tips of the germ-hyphæ attached themselves to the surface of the cuticle, and then *dissolved* their way in, discoloring and destroying the cell walls and cuticle in the immediate neighborhood." It would plainly be impossible for the same enzyme to attack both cellulose and cutin. Again it may be stated, that the *death* of the affected tissue is distinctly a different phenomenon from its utilization by the fungus as food. What then occurs?

There can be no reasonable doubt that some soluble substance produced by the fungus diffuses through the cuticle and cell walls and kills the cells some distance ahead of the filaments. Following this, the filaments, probably under the influence of chemotropism, invade the lifeless tissue in all directions, mostly

by simple mechanical pressure aided by cellulose or pektose-dissolving enzymes. It has not been the writer's observation, however, that the filaments penetrate to the interior of the cells to any great extent. Occasionally a case is seen as shown in *fig. 2*, but here there appears to be no dissolving or swelling of the wall, but a breaking through by simple mechanical pressure. The various other enzymes then become active and the tissue is completely destroyed.

FIG. 2.—Filament of *Botrytis cinerea* penetrating a cell.

The question still remains as to the nature of the poisonous substance. It has already been mentioned, and is a well known fact, that the formation of oxalic acid almost invariably accompanies the growth of Botrytis, being brought about by the oxidation of carbohydrates. Analysis of the mycelium extract also shows this substance in considerable amount. DeBary considered the possibility of this substance being concerned in the effect of the fungus upon vegetable tissue, but discarded the idea on the ground that solutions of pure oxalic acid do not give the entire characteristic effect of a Botrytis extract or culture. The constant occurrence of this substance has seemed to the writer at least suggestive, and its effect upon plant tissues has been studied to some extent. It is of course well known that oxalic acid causes plasmolysis and death of cells if sufficiently strong.

Lettuce leaves were placed by the writer with the petioles submerged in Botrytis extract, and 0.125 per cent., 0.5 per cent., and 1 per cent. oxalic acid. After a few hours of this treatment a remarkably similar effect was observed. All showed marked softening of the tissue where touched by the liquid, followed by collapse and shriveling. The effect of the weakest solution of the acid, 0.125 per cent., was as marked as that of the extract. The boiled extract showed no appreciable difference in effect to the eye from the unboiled. In all five cases the affected tissue had exactly the appearance of having been boiled. The chief

difference in appearance was that the acid had a bleaching effect upon the tissue, while that in the extract became darker colored. Microscopically some similarities and some differences were noted. The cells in the acid were strongly plasmolyzed and killed. In collapsing they pulled apart from one another, so that even in the 0.125 per cent. solution the tissue was almost as completely macerated as in the Botrytis extract. It may be stated conservatively that in a 0.125 per cent. solution of oxalic acid the death of the cells and consequent softening of the tissue was fully as marked as in an average Botrytis extract. The cell wall was somewhat swollen in the acid, but not in the extract. The disintegration of the protoplasm was more marked in the extract. De Bary found in a sample of Sclerotinia extract 0.319 per cent. oxalic acid. The writer has found over 2 per cent. in the mycelium extracts from old cultures to which sugar had been abundantly supplied. It can therefore scarcely be doubted that in such an extract the acid alone would have a marked effect upon plant tissue, whether or not the liquid had been boiled. It is, however, a reasonable objection to judging the effects of the growth of the fungus by those of such extracts, that with germinating conidia or filaments rapidly advancing into new tissue no such amounts of oxalic acid could be expected to accumulate. It is therefore necessary to consider the effects of much more dilute solutions.

Solutions of 0.01 and 0.05 per cent. were prepared, and their effects upon vegetable tissue studied as before. When thin sections of lettuce petioles were placed in these weak solutions, together with others in pure water, the effect was still strongly marked. Within a few minutes a bleaching was evident, and soon the green color had entirely disappeared. Plasmolysis did not occur, but an effect almost identical with that shown in the most newly affected tissue in *fig. 1* soon developed. Especially noticeable is the granular appearance of the affected cell contents, particularly near the walls. Whether this is due to the deposit of an insoluble oxalate, or to a change in the protoplasm, is difficult to determine. However this may be, it appears that

the cells are killed by poisoning, without plasmolysis, both by the fungus itself and by very delicate solutions of oxalic acid, while with the stronger solutions obtained in mycelium extracts or made up directly with the acid the same effect is accompanied by plasmolysis. The softening and bleaching effect of the acid even in 0.01 per cent. solution was very evident to the naked eye.

The production of gallic acid from tannin by the growth of Botrytis has been described above. In a 1 per cent. solution of this substance a lettuce leaf petiole became softened and collapsed much as in the Botrytis extract, but more slowly. A dark color was produced much as in the extract, rather than the bleaching by oxalic acid.

It seems to the writer that we have to seek in some such explanations as these the cause of the poisoning and death of the cells of tissues attacked by Botrytis. Most of those who have considered the subject before seem to have overlooked the fact previously stated that two distinct effects are brought about by the fungus, and that no one substance can produce both of these. That the first or poisonous substance is not an enzyme is plainly proven. That it is oxalic acid seems more than probable from the regular occurrence of this substance and its described effects. The discoloration of the cell walls which the fungus produces, rather than the bleaching brought about by a solution of oxalic acid, is readily explained by the decomposition of tannin or some similar compound.

There may now be considered briefly, in the light of this theory, the tendency in this species to require saprophytic nourishment preliminary to its parasitism. If spores of Botrytis are sown in water upon living tissue no infection ordinarily results. If a drop of prune juice or any good nutrient be added, infection often takes place, under the conditions previously enumerated. This is explained in a general way by the statement that the fungus acquires *vital energy* or *vigor*, by such nourishment. Expressed more definitely, the idea has been that the production of the cellulose-dissolving enzyme is stimulated by this

means, and that the varying ability of the fungus to infect directly depends upon a varying power of enzyme formation from the reserve material of the conidia. The theory advanced in the present article is easily adapted to the known conditions in this respect. The addition of a nutrient solution would at once bring about the formation of oxalic acid, poisoning the subjacent tissue and permitting the entrance of the hyphae through the dead cuticle and epidermis by mechanical force under the influence of chemotropism. That this effect would be favored by the conditions under which Botrytis attacks living tissue needs no explanation; thickness of cuticle and epidermis, and vital activity of the host being the most potent controlling factors. Without such nourishment the ability of the germ hyphae to enter the plant depends upon the amount of acid formed from the reserve material in the conidia. In the linden and rose diseases studied by the writer (13) the conidia formed were found to be of unusually large size. Marshall Ward found in the lily disease, where infection took place as well without saprophytic nourishment as with it, that the conidia were much above the ordinary size, and observation in general shows that where Botrytis grows actively and luxuriantly upon living plants the conidia are very large. Are not these points suggestive of an increased power of infection due to the increased amount of reserve material?

SUMMARY.

Briefly stated, the main point of this article is as follows:

In the best known works upon the parasitism of Botrytis and similar fungi too much importance has been ascribed to a cellulose-dissolving enzyme. Two stages in the process should be clearly distinguished: first, a poisoning and killing of the cells; and second, their disintegration and utilization as food by the fungus. The first effect appears to be produced by a substance which there are strong reasons for supposing to be oxalic acid, formed by the fungus as a by-product of its metabolism. Following this, a number of different enzymes are secreted which digest the various constituents of the tissue. The identity of

these enzymes probably varies somewhat in different cases, and apparently more than one occurs which affects different forms of cellulose. The substance causing a marked swelling of the cell wall in the lily Botrytis, studied by Ward, and the turnip bacterium by Potter, appears to be an enzyme not ordinarily produced by *Botrytis cinerea*.

In conclusion, it may be remarked that these results have a very suggestive bearing upon the parasitism of many other fungi which bring about a rapid destruction of the host tissue.

MASSACHUSETTS AGRICULTURAL COLLEGE,
Amherst, Mass.

LITERATURE CITED.

1. DE BARY, A., Ueber einige Sclerotinien. Bot. Zeit. **44**: 377. 1886.
2. WARD, H. MARSHALL, A lily disease. Annals of Botany **2**: 319. 1888–89.
3. KISSLING, E., Zur Biologie der *Botrytis cinerea*. Hedwigia **28**: 227. 1889.
4. WEHMER, C., Entstehung und physiologische Bedeutung der Oxalsäure, etc., Bot. Zeit. **49**: 233. 1891.
5. BÜSGEN, M., Ueber einige Eigenschaften der Keimlinge parasitischen Pilze. Bot. Zeit. **51**: 54. 1893.
6. MIYOSHI, M., Ueber Chemotropismus der Pilze. Bot. Zeit. **52**: 1. 1894.
7. ————————, Die Durchbohrung von Membranen durch Pilzfäden. Jahrb. Wiss. Bot. **28**: 269. 1895.
8. POTTER, M. C., Rottenness of turnips, etc. Journ. Board Agr. **3**: 120. 1896.
9. ————————, On a bacterial disease of the turnip. Proc. Roy. Soc. **67**: 442. 1900.
10. BEHRENS, J., Beiträge zur Kenntniss der Obstfäule. Centralb. Bact. Par. 4^2: 514. 1898.
11. NEWCOMBE, F. C., Cellulose enzymes. Annals of Botany **13**: 49. 1899.
12. NORDHAUSEN, M., Beiträge zur Biologie parasitärer Pilze. Jahrb. Wiss. Bot. **33**: 1. 1899.
13. SMITH, R. E., Botrytis and Sclerotinia. BOT. GAZ. **29**: 369. 1900.
14. GREEN, J. REYNOLDS, The soluble ferments and fermentation.

THE DEVELOPMENT OF VEGETATION IN THE MORAINAL DEPRESSIONS OF THE VICINITY OF WOODS HOLE.

CHARLES H. SHAW.

(WITH SIX FIGURES)

FEW regions afford better opportunity for observing the stages in the history of small swamps than the vicinity of Woods Hole, Mass. The land of the neighborhood, a few outcrops of Cretaceous strata excepted, consists of the eroded mass of a terminal moraine. Clay, sand, and fragments of stone grading up to huge bowlders constitute the country rock. Indenting the surface of this mass of débris are innumerable specimens of the peculiar depressions known to geologists as "kettle holes." In such hollows ponds and lakes have formed, each one the first term of a long series ending in its own obliteration. The changes by which the pond is destroyed, and in which vegetation plays so important a part, furnish a subject of absorbing interest. Many workers have gone far toward giving us an understanding of such a history. However, our knowledge is not complete, and questions which arose in the work at the Marine Biological Laboratory have led to this attempt to answer them. The present paper may be conveniently divided into three sections.

PHYSICAL FACTORS — EROSION AND DEPOSIT.

The authors who have pointed out the interesting and important part played by vegetation in the filling of ponds have possibly minimized the purely physical factors. At times the latter play a leading, and at times, as in cases mentioned later, an exclusive part.

The amount and the character of the silt washed down varies greatly with the nature of the surrounding surface. Where the latter has been disturbed by man, the quantity of material brought in, even by summer rains, is often astonishing.

Fig. 1 shows a pond in the edge of the village, adjoining a road. On July 2 there was a thunder shower lasting for about an hour. During that time a deposit was formed at one corner of this pond some $25^{sq.\ m}$ in area and $30–90^{cm}$ in depth. Four weeks later came another, less violent shower. The surface of the first deposit was cut down part way across by $40–50^{cm}$, and

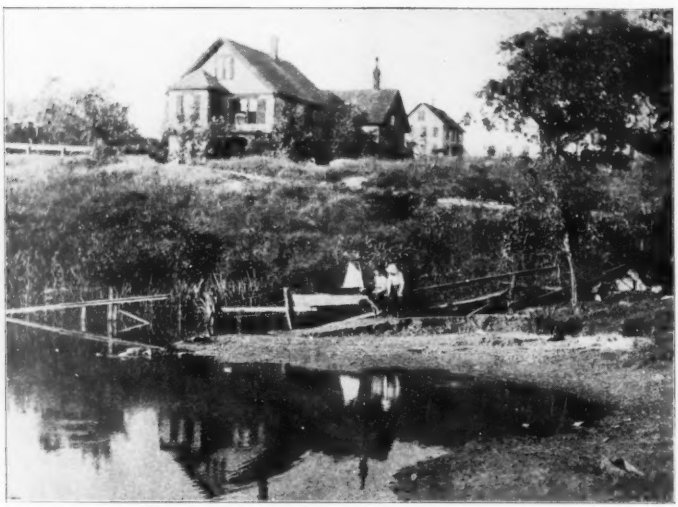


FIG. 1.—Pond in edge of village.

the material, aggregating many tons, borne farther out. The obliteration of this pond within two or three years may be expected. Of course, we are here dealing with highly disturbed conditions, but nevertheless the case may serve to enlarge our ideas as to the rapidity with which silt may be moved down. During the early period immediately following the retreat of the glacier, and before vegetation gained a footing, deposits in these depressions must have been made with enormous rapidity.

Where the pond is surrounded by grassy fields, the washing-in process is much restricted. That it still goes forward, however, one need only examine the pond margin to learn. A zone

of fine earth and sand encircles the pool, pushing slowly inward. If the contour of the surrounding land is such that the rain rivulets cut out a gully, the zone of silt deposit opposite its mouth indents the pond as a sandy or gravelly delta. These borders and deltas of silt become the seat of well-marked plant societies. *Gratiola aurea* in particular occurs with regularity, and its yellow blossoms may indicate to the eye at a distance the limits of such deposits. If the pond is situated in the deep woods, results are produced which are apparently paradoxical, and will be discussed below.

NOTES UPON SUCCESSIVE STAGES.

Large holes present, of course, the earliest phases, and in the small ones the more advanced conditions are found. As a type of the former we may chose Long pond, near Falmouth village. It is about 2½ kilometers long, and reaches a depth of 28 meters. The shores are of the usual morainal materials, and in some places precipitous. As usual in such cases, it is without drainage, yet its depth and area are such that its water is well aerated, and, as analyses have shown, is nearly free from organic matter. The scanty vegetation admits of being described with some exactness. In the body of the pond no plants are seen. Near the shore appear some filamentous algae, and four species of flowering plants. The latter are distributed in two zones, sharply and surprisingly separated by one destitute of vegetation.

Limnanthemum lacunosum forms a continuous belt, but one which *never touches the shore line*. Soundings taken all around the lake show that the Limnanthemum zone is here confined to water between 0.6 and 3.9^{m} in depth. These soundings were made in August, when the water was about 20^{cm} lower than the line seen on the rocks. Limnanthemum, then, is here able to anchor on the bottom and float its leaves in water somewhat exceeding 4^{m} in depth. *Lobelia Dortmanna* appeared in about the same zone, growing entirely submerged, and could be seen from the surface through the transparent water. For obtaining specimens a bathing suit was useful. Many of the plants had put forth long scapes

at the time, but these could not reach the surface, and the blossoms decayed without opening. Like the preceding species, this did not occur in the shallow water next the shore line. *Gratiola aurea*, in its strictly hydrophilous form, was found in company with these also, but did not appear to flourish.

Between the zone of these three plants and the shore line was a space of open water, devoid of phanerogamic vegetation.

On the shore line, its roots submerged, *Euthamnia* (*Solidago*) *graminifolia* appeared, and its rich border of bloom nearly circuited the pond. That the zone of Limnanthemum and Lobelia did not extend inward till met by Euthamnia seemed a circumstance needing explanation, especially since both the former flourish elsewhere in very shallow water.

At some points wave-marks on the bottom had been seen, and it was noticed that the outer limit of these coincided with the shoreward limit of the Limnanthemum zone. Sandy silt in some quantity was coming in from the surrounding slopes. Limnanthemum plants along the shoreward margin of the zone were found buried in sand at the bottom, and dying. There seemed then reason for believing that the shoreward limit of this zone was set by the action in shallow water of the wavelets in shifting the silt, and burying the bottom-growing vegetation.

Fig. 2 is a graphic illustration of action of this sort, drawn from a large pond on an adjacent island, called West end lake. Silt is coming into the pond from the low surrounding hills. At one spot a great bowlder, out from the shore line, breaks the wavelets, and the silt has run out to it as a sandy peninsula whose curving sides represent the hyperbola of the broken wave action. Thus the outlying bowlder plays a rather fantastic part in the growth of the land, and shelters a certain area from the smothering action of material which comes from the shore. The nearly clean, sandy bottom of the margin of this lake is due to the fact that the shallow water vegetation is constantly overwhelmed by the encroaching silt. Sheltered behind the bowlder, a colony of *Juncus militaris* is growing.

At Long pond, Euthamnia, nevertheless, grew just at the

shore where the danger of burial was greatest. Explanation of this fact was found by digging, for the plant possessed running stems, penetrating the sand in all directions in a manner similar to sand binders, and like them was able to grow out as fast as buried. Limnanthemum and Lobelia have no runners, and so are driven to the zone beyond.

At the south end of Long pond, the slopes surrounding are of

FIG. 2.—West end lake.

such a contour that washings would be swept toward a certain portion of the shore line. Moreover, the surface near this portion has been broken by cutting a road, and silt is brought in great quantities. Where this material reaches the shore line a sandy beach is formed, and from the beach it has advanced into the pond some 30 meters as a submerged delta. The diagram (*fig. 3*) may aid in making the case clear. The outline of the delta is shaded; the sandy beach represented by the line *a–b*. Now the Limnanthemum-Lobelia zone (indicated by the small circles) follows closely the outline of the submerged delta, and the Euthamnia zone on the shore (outlined by the scroll) is interrupted by the sandy beach. The fact is that the former

zone is driven outward by the advancing silt, and the latter interrupted altogether, despite the running stems of Euthamnia. Rowing around above the edge of the delta, and looking down through the transparent water, one can see colonies of Lobelia growing in the little hollows around the margin of the deposit. If the latter should advance, the fate of these colonies is easy to predict.

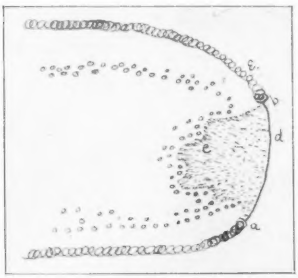


FIG. 3.—Diagram of south end of Long pond.

Fig. 4 is from a photograph taken from *c*, and including the shore line from *d* to *e*. From *d* to *b* may be seen the sand beach, from *b* to *e* a portion of the Euthamnia zone, which continues unbroken a kilometer or more from that point.

Somewhat more advanced than that of Long pond is the stage of a pond near by. The latter is smaller, and analyses here show a considerably greater proportion of organic matter. Portions are shallow, and in such Nuphar and Pontederia are making dense beds. Along the margin Euthamnia finds the space disputed by *Lysimachia stricta*, Lycopus, and *Coreopsis roseus*. Running subterranean stems are possessed by all these plants, and they are able to defy burial by silt in moderate quantities.

The history of the destruction of the shallow pool has been often described. The encroaching of the plants from the margin, the increase of such plants as Nuphar and Nymphaea in the body of the pool till a footing is afforded for less anchored forms, and the consequent formation of the floating mat, may be here passed over with a few local notes. All stages may be splendidly seen in this region. Among recollections of the summer are vivid ones of trying to reach attractive patches of Xyris or Drosera in bloom, and learning that the apparent ground was only floating mat with ominous depths below.

Nuphar and Nymphaea take an important part in the first

formation of the floating vegetation. When a pond happens to be of nearly uniform depth, of 1^{m} or less, Nymphaea may grow in a luxuriance almost incredible. In such a pool, perhaps 150 meters in diameter, near Succonesset point, water lilies were growing and blooming in such profusion that when it was found in July the surface of the pond seen through the trees gave the

FIG. 4.—South shore of Long pond.

effect of an unbroken sheet of white. Limnanthemum and Brasenia are in some cases important constituents of the first pond vegetation.

In certain places *Hypericum boreale* takes a leading part. This plant shows an interesting dimorphism. It grows submerged as a sparingly leafy unbranched axis, weak and slender, erect by its own buoyancy. When it reaches the surface, however, it breaks out into a strong branching herb, sustaining masses of aerial foliage from enlarged stems floating horizontally on the surface. At Flax pond, in about 30^{cm} of water, it forms thus continuous floating masses many square meters in area.

When such anchored forms, especially the strong ones like Nuphar, gain a good footing, the floating mat vegetation follows apace. Several species of Utricularia aid greatly in this process, by means of their floating and branching tufts. Sphagnum and other mosses, Carices, Xyris, and Drosera appear.

In still further building the mat, and in giving it firmness, *Decodon verticillatus* plays a leading part. Several adaptations give it its preeminence, namely, the firmness of its woody roots and stem bases; its ability, nevertheless, to grow almost floating, only slight support being necessary; and its power of propagating from the tips of its shoots wherever they touch the water. The woody parts mentioned are clothed with thick layers of aerenchyma. Probably this tissue is not only a means of respiration, but also of importance in floating the plant. Decodon occurs almost universally in the yielding ponds.

We have seen that in Long pond, an open lake, the vegetation is purely hydrophilous. About the time of the formation of the floating mat, the general conditions rapidly become xerophytic. Following Decodon, and finding footing on its stools, appear a host of xerophilous shrubs. *Clethra alnifolia*, *Azalea viscosum*, *Vaccinium corymbosum*, *Ilex verticillata*, *Myrica cerifera* and *M. Gale*, *Andromeda ligustrina*, *Leucothoe calyculata*, sometimes Cassandra and others, rapidly transform the floating mat into a swamp thicket. It is observable that these shrubs, though representing widely different alliances, have a certain common facies. All have alternate, simple, lanceolate, nearly entire and nearly smooth leaves.

Decodon passes away before the shrubs, and in due time seedlings of trees begin to appear. As these trees, often wholly Chamaecyparis, grow, the shrubs are overtopped and yield, and the series enters a final cycle as a Chamaecyparis swamp.

Three such swamps in the immediate vicinity of Woods Hole afford beautiful illustrations of these final stages. For the sake of description we may designate them as *x*, *y*, and *z*.

In *x* the water still stands for most of the year between the stools. Chamaecyparis trees, 10–25 cm thick, rise from these

stools, and only close to their bases may the visitor here find footing. Clumps of *Vaccinium corymbosum* and Leucothoe show that these shrubs survive shading better than the other members of the bygone thicket. Between the trees a rod may be thrust

FIG. 5.—Chamaecyparis swamp.

down 5 meters without touching bottom. If one succeeds in making his way to the center, he finds a deep and dark pool perhaps 50 meters in diameter, of whose appearance some idea may be gained from *fig. 5*. On its surface is no vegetation, except a border clinging to the spreading roots of the trees. Long

tufts of *Usnea barbata*, simulating *Tillandsia usneoides*, hang from the trees, and if the beholder is of an imaginative disposition, the weird scene becomes for him a recess of some sub-tropical swamp.

In *y* the water is less in evidence, and sometimes disappears from the surface for many weeks during the summer. The trees average slightly larger. In depressions between their stools Sphagnum is growing; on the stools themselves, thick cushions of other mosses. Shrubs are nearly absent, the lower portions of the trees' trunks are branchless, and one looks through sombre forest aisles, darker and more still than those of a pine forest. No pool is found at its center; matters have gone farther here, and the encroaching vegetation has covered the one time pond completely over.

In swamp *z* water is ordinarily absent, and the ground is firm enough that one may walk where he will. The trees are noticeably larger, some reaching a diameter of 45^{cm}. *Osmunda cinnamomea* grows in abundance. Young cedar trees are scarcely found, and one realizes that he beholds the penultimate term of the long series.

THE ORIGIN OF POND-ISLANDS AND ATOLLS.

In frequent instances the filling-up of the pond takes place in a fashion seemingly paradoxical. Instead of the deposit gradually encroaching from the margin, an island forms in the center and leaves a narrow belt of open water about the edge of the pool.

Fig. 6 shows a case of pond perhaps 15 meters in diameter, near Quisset harbor. That a pond should begin by filling up in the middle is a fact calculated to arouse the curiosity of a layman. The sharpness of the ditch and the frequency with which it appears call for an understanding of its origin. Perhaps it is the same as described by MacMillan[1] in connection with "plant atolls." Yet the hypothesis put forth in the paper cited seems scarcely applicable to the present cases.

[1] On the occurrence of Sphagnum atolls in central Minnesota. Minnesota Botanical Studies 1: no. 9. 1894.

If the pond were larger and deeper than the one shown in *fig. 6*, a pool would remain in the center and we should have a ring of vegetation between the ditch and the central pool. Indeed there is at least one such veritable atoll in the vicinity at present in question, and it is found in a larger basin, perhaps 100 meters in diameter.

FIG. 6.—Pond-island near Quisset harbor.

The view is here taken that this atoll at least differs from a pond-island only in the fact that a larger kettle-hole is involved, and that in consequence a ring of vegetation is formed instead of an island. The problem would then resolve itself into accounting for the marginal ditch.

Professor MacMillan suggests that the ditch owes its origin to a fall and subsequent rise in the water level of the pond, and the spreading of the water beyond its one time boundaries. In the present cases some facts seem to call for more explanation than this hypothesis affords. The ditches, though perfectly sharp, are quite shallow, having an average depth of about 70^{cm}. Promising territory as this would be, aquatic plants showed little disposition to invade it. An artificial excavation of any sort is

generally soon seized upon, and the fact that these marginal ditches remain devoid of vegetation, not being even bordered with the usual water margin plants, suggested to the writer that there must be some cause which prevents the growth of vegetation in that zone, and that this might be identical with the one which originally gave rise to the ditch. A rise of water, in conjunction with such a cause, might make a compound atoll.

Atkinson, in his *Lessons in botany*, makes additional suggestions in regard to the origin of the ditch, one of which is that it is caused by the shade of trees and shrubs growing on the solid land, and thus giving low vegetation around the border of a pool a poor opportunity. However, the northern edge of a pond is quite exposed to the sun during the hours of midday, yet the ditch exists there as markedly as anywhere else.

It was observed that formations of this character were found only in wooded districts, or on those recently cleared. Portions of the islands of the neighborhood are treeless, and in these localities the ponds were filling up from the margin in the well known manner.

Another fact was eventually noticed, namely, that the ditch varied in width, and that this variation bore a constant relation to the contour of the surrounding surface. The ditch is always widest where, from the arrangement of the surrounding slopes, the most material is washed in. That fact seemed to harmonize ill with ideas of erosion and deposit.

When the character of the material brought in was considered, however, an explanation of the different facts began to appear. The forest floor around is of humus, and covered with a close felt of roots, mosses, and mycelia. It does not take a long examination to convince one that ordinary erosive action of rain has literally ceased. Only fallen leaves and other organic matter is washed into the pond. Such is brought in, however, in quantities, and young plants which might start around the edge are constantly smothered. The bottom of the ditch may be seen always covered with quantities of dead leaves; and reaching into the water one can grasp great handfuls in all

stages of decay. New material, brought in with every shower, adds to the decaying mass, and produces a zone nearly destitute of growing plants, widest where the washings of the forest floor are most swept in.

Organic material, unmixed with sand or earth, in decaying forms solid strata very slowly. A considerable period must elapse before this zone is filled up. Even the detritus thus slowly formed may not remain at the margin, *for the island of vegetation is a floating one*, and the real bottom of the pool is more or less basin shaped. The islands are in fact floating mats, and are likely to afford only a very doubtful footing, but by felling a tree upon one somewhat smaller than the one shown, it was possible to reach the center and learn that in that case there are 2 or 3 meters of water in the center on which the floating island rests. The detritus resulting from decomposition of matter in the marginal ditch slides into the deeper parts of the pool, and thus the stage of the ditch is yet more prolonged. After the island becomes fixed, the ditch still fills very slowly. Even after the central area has been occupied by trees, it often may still be plainly traced.

SUMMARY.

In the filling-up of ponds, the activity of vegetation is in cases second to the physical factors of erosion and deposit. In open pools, anchored plants with floating leaves are often confined to a zone somewhat separated from the shore, their approach to the shore line being prevented by silt which is swept in, especially where the latter is shifted by wavelets. The physical factors in that zone thus exclude the organic. Plants of the shore line in such cases have running stems similar to those of sand binders, which enable them to escape death by burial.

The vegetation of the large open morainal pool, though undrained, may be purely hydrophilous. About the time of the formation of the floating mat the conditions appear to become xerophytic.

The marginal ditch which surrounds pond islands and atolls is in this region, at least, formed only in the woods, where a

dense felt of humus vegetation protects the ground from erosion. Fallen leaves and other organic materials swept from the forest floor into the edge of the pool tend to smother the vegetation which might grow there, and thus is produced a belt of open water, surrounding an island, or if the pond is larger a ring of vegetation.

TEMPLE COLLEGE,
Philadelphia.

A MORPHOLOGICAL STUDY OF THE FLOWER AND EMBRYO OF SPIRAEA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXXVI.

JONATHAN E. WEBB.

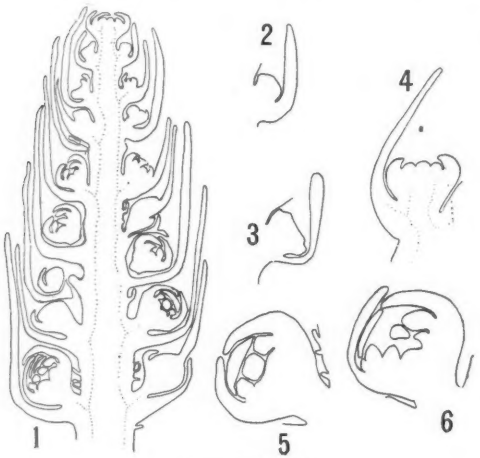
(WITH TWENTY-EIGHT FIGURES)

THE material used in preparing this paper was obtained largely from the Washington Park greenhouse, Chicago. Specimens of *Spiraea salicifolia* in various stages of development were secured from Grand crossing and East Chicago, Illinois, and from Marquette, Michigan. The species chosen for study was *Spiraea Japonica*, and this was supplemented by *S. astilboides planiflora* and *S. salicifolia*. Specimens were killed in chrom-acetic acid, Carnoy's mixture, and Flemming's mixture. All material was imbedded in paraffin, cut in serial sections with a microtome, and stained on the slide. Delafield's haematoxylin alone or in combination with erythrosin or iron alum was used chiefly, but cyanin and erythrosin, or the safranin, gentian-violet, orange G combination were used in certain cases. The Carnoy mixture was perhaps the most useful in every respect as a killing agent, and gave very satisfactory results.

ORGANOGENY OF THE FLOWER.

Spiraea affords an excellent opportunity for the study of the development of floral organs, as a longitudinal section of a spike gives many stages (*fig. 1*). At an early stage the rudiment of the flower appears as a protuberance in the axil of a bract (*fig. 2*). Five rather narrow ridges arise on the margin of this protuberance, and these ridges are the beginnings of the sepals, two of which are shown in section in *fig. 3*. Next there appears within this circle of ridges a whorl of papillae, the beginning of the inner five stamens, each opposite a sepal, and that this whorl does follow next is shown by the greater development of stamens

in that position (*fig. 10*). Immediately the third whorl of papillae appears, the individual members alternating with the second, and forming the second cycle of stamens, smaller and shorter than the first, and at a greater distance from the floral center (*fig. 9*). Contemporaneously with the second whorl of papillae, and while the first three whorls have as yet merely roughened the surface of the floral protuberance, two ridges, each strongly curved and with concave parts facing each other, arise at the center of the receptacle (*fig. 7*). These ridges fail to develop on the inner face except at their extremities, and the result is two carpels with cavities facing each other and nearly filled by the large development of the ridge-ends, which form the placentae. The transverse sections in *figs. 8* and *9* show this cavity, and how it is filled by the placentae before the development of the ovules. Although there are five carpels in *Spiraea salicifolia* and two in *S. Japonica*, leaving opportunity for variation from two to five, no evidence was found of the rudi-



Spiraea Japonica.

FIG. 1.—Longitudinal section of a young spike, showing floral development. × 23.

FIG. 2.—Floral papilla in the axil of a bract. × 54.

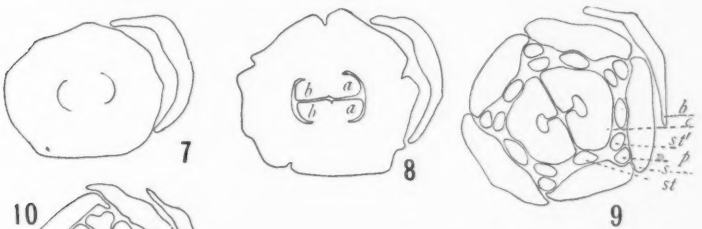
FIG. 3.—A later stage showing first appearance of sepals. × 54.

FIG. 4.—A stage showing sepals and stamens. × 54.

FIG. 5.—Longitudinal section passing through one side of the center of a flower, showing three stamens. × 54.

FIG. 6.—A longitudinal section of the same flower exactly through the center, showing that the capillary cavity is not yet closed above, and showing first appearance of petals. × 54.

ments of more than two carpels in the latter species. Once the form of the carpel is established, a rather uniform enlargement of all parts gives the necessary room for the many ovules. At the stage indicated in *fig. 9* the last cycle of floral parts, that of the corolla, has appeared, the petals alternating with the sepals, and lying just within their edges.



Spiraea Japonica.

FIG. 7.—Transverse section of flower at the base of the carpellary layer. × 54.

FIG. 8.—Section of same flower at point of maximum development of placenta; *aa*, *bb*, the ends of the two ridges enlarged, thickened, and curved. × 54.

FIG. 9.—Transverse section immediately above the plane of insertion of stamens and petals upon the receptacle; *b*, bract; *s*, sepals; *st*, stamen of the inner whorl; *c*, carpel; *st'*, stamen of the outer whorl; *p*, petal. × 54.

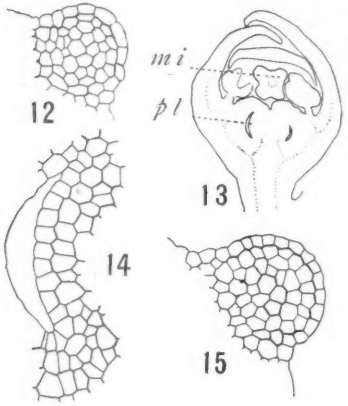
FIG 10.—Transverse section immediately above the top of the carpels, with ten stamens in section. × 54.

FIG. 11.—Transverse section near top of the largest stamens. × 54.

This development of floral parts in Spiraea shows that the order is as follows: sepals, inner stamens, carpels and outer stamens, petals (*figs. 9, 10*).

The development of microsporangia and megasporangia is rapid, and maturity is reached in a week or two; the megasporangia, however, attain their full development later than the microsporangia. At an early stage the anthers have, to some extent, become rounded and enlarged, while the carpellary cavity even has not yet been closed over above (*fig. 6*). Again, when the four microsporangia of an anther are well marked, the

placentae are still wholly undifferentiated (*figs. 14* and *15*). The ovules are yet without integuments at a time when the microsporangia have a well marked tapetum and the sporogenous tissue has neared the spore mother cell stage (*figs. 17* and *18*). The initiation of the integuments on the ovules occurs at the time of the tetrad stage of the microsporangia, or while the pollen grains are separating and becoming round, and before the dominant megaspore has been determined. At this stage the microsporangium is inactive until the pollen is shed.



Spiraea Japonica.

FIG. 12.—Transverse section of a young stamen, showing homogeneous character of the archesporial mass. × 54.

FIG. 13.—Section through center of flower after carpellary cavity is complete, showing placenta; *mi*, microsporangium; *pl*, placenta. × 54.

FIG. 14.—Longitudinal section through placenta of same flower. × 350.

FIG. 15.—Microsporangium of same flower. × 350.

THE MICROSPORANGIUM.

In the development of the flower the second whorl of papillae to arise on the receptacle is that of the stamens. These papillae early become stalked below, enlarged and rounded above. In Typha[1] this enlargement does not occur until much later. While the placenta is still composed of large, undifferentiated cells, and before the appearance of the ovules, the microsporangia have attained their characteristic quadrilocular form, and the epidermal layer is separated from the hypodermal by heavier walls (*figs. 12* and *15*). This is the first differentiation of any kind in the cells of the microsporangium, characterized by size of cells, thickness of cell walls, or depth of stain; and no archesporial cell or plate of archesporial cells appears at any stage in a close

[1] SHAFFNER, BOT. GAZ. **24**: 94–95. 1897.

series of preparations. Shortly thereafter the peripheral layer of the hypodermal mass may be distinguished by its lighter color and incipient periclinal division, which results in two narrow layers of cells derived from the archesporial tissue, as shown in *fig. 18*, the latter showing this division of the hypodermal layer partially completed, and with no precise differentiation of the cells of the included sporogenous mass. For although the separation of tapetum from sporogenous tissue has already been made, there is nothing which shows this conclusively but the peripheral position of a layer of cells, and the number of cells in a cross section equal, as it is, to the number in later stages. On the other hand, the cells of the tapetal cylinder clearly show by their shape and intimate association with those of the central sporogenous mass that the origin of tapetal and sporogenous cells is one. The chance of position alone keeps the former from being sporogenous cells. Their position, however, compels them to act as purveyors of nutrition to the other sporogenous cells, a task for which they are eminently fitted by their kinship. Yet by the very accomplishment of this task they are so changed as to be incapable of acting, like their sisters, as spore mother-cells.

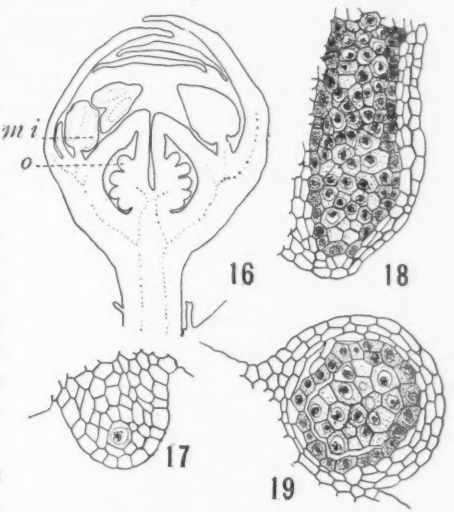


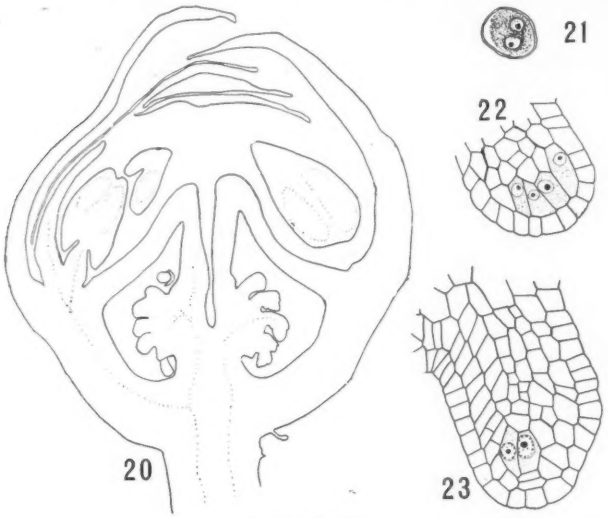
FIG. 16.—*Spiraea astilboides planiflora.* Longitudinal section of a flower, showing all parts, including petals and ovules; *mi*, microsporangium; *o*, ovule. × 54.

FIG. 17.—Ovule of same section, with tapetum cut off. × 350.

FIG. 18.—Microsporangium of same section, with division to form the endothecium. × 350.

FIG. 19.—*Spiraea salicifolia.* Transverse section through microsporangium with well developed tapetum. × 350.

Although such an explanation of the tapetal layer is impossible for many microsporangia, as in Cnicus,[2] yet its possibility has been suggested by Coulter in Ranunculus.[3] By gradual changes the tapetal layer is clearly differentiated from the spore mother-cells until it stains more deeply, has a more homogeneous appearance, and acquires a tendency to separate from the spore



Spiraea Japonica.

FIG. 20.—Longitudinal section through flower with all parts represented and showing beginning of the integuments. × 54.

FIG. 21.—Pollen grain with two nuclei at time of shedding. × 550.

FIG. 22.—Longitudinal section of young ovule with four archesporial cells. × 550.

FIG. 23.—Longitudinal section with the first layer of tapetal cells and two potential megaspore mother-cells. × 550.

mother-cells, although several cells in the layer might from their appearance be either tapetal or sporogenous (*fig. 19*). This stage is followed by the thickening of the tapetum, until it becomes a layer rich in food material, homogeneous throughout,

[2] COULTER, Contributions to the life history of Ranunculus. BOT. GAZ. **25**: 73–88. *pls. 4-7.* 1898.

[3] COULTER, *ibid.*

surrounding the spore mother-cells in a late synapsis stage, and itself surrounded by two layers of narrow, lightly staining wall cells. This condition persists for some time as regards the tapetum, until one of the wall layers is absorbed and the other has become very much thickened at the stage of the division of the spore mother-cells into tetrads; then the microspores round up, and at the time of shedding they have disorganized the tapetal cells and have absorbed their contents. Of the two layers between tapetum and epidermis, mentioned above, the inner has now disappeared, having been absorbed by the tapetum for the benefit of the sporogenous tissue. The outer or endothecium has become a thick layer by reason of the enlargement of its cells in which the nuclei are not conspicuous, but the walls have characteristic thickenings. At this stage there are two nuclei in the pollen grain (*fig. 21*).

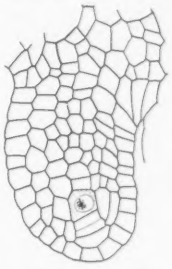


FIG. 24.— *Spiraea Japonica.*— Longitudinal section through an ovule showing a row of three tapetal cells and one large megaspore mother-cell. × 550.

THE MEGASPORANGIUM.

The comparative rate of development of stamens and ovules has already been stated. Long-before the appearance of the integuments, and while the ovules are but slightly developed on the placenta, several hypodermal cells at the tip of the ovule become enlarged, and their nuclei differ in size and arrangement of contents from those of neighboring cells (*fig. 22*). This mass of archesporial cells in the ovule of Spiraea is comparable to that found in *Rosa livida* by Strasburger.[4] Ensuing periclinal division results in forming two masses, the hypodermal being the tapetal mass, and the other the sporogenous mass. Successive divisions of the cells of the tapetal layer by periclinal walls result in adding much to the length of the ovule and the distance from the sporogenous tissue to the epidermis. Periclinal divisions in the epidermis itself also add to the length of the ovule

[4] STRASBURGER, Angiospermen und Gymnospermen. 1879.

(*fig. 25*). This method of division causes a radial appearance in a longitudinal section from the region of the embryo sac to the micropyle, which has been figured for *Rosa livida* by Strasburger,[5] and occurs in other members of the rose family, such as *Pirus Malus*. There are variations in the number of megaspore mother-cells which enlarge for division. This number is usually one, but often two or three begin to divide, and then

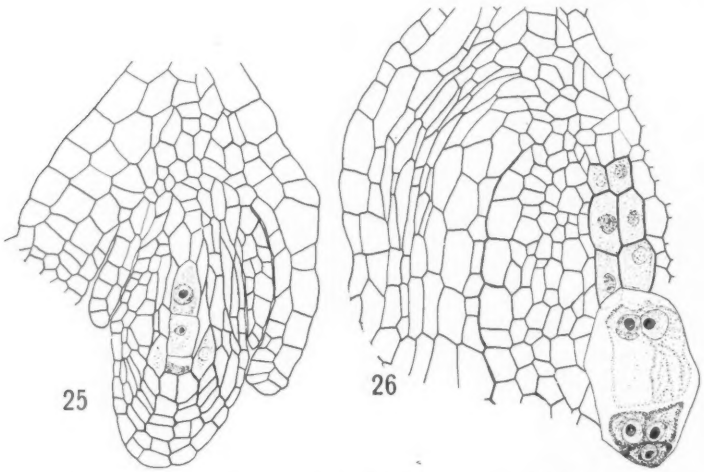


FIG. 25.—*Spiraea Japonica*. Longitudinal section of an ovule with integuments, large tapetal development, three large potential megaspores, and several megaspores breaking down. × 550.

FIG. 26.—*Spiraea Japonica*. Longitudinal section of mature embryo sac normally developed, showing thick nutritive cells in the chalazal region. × 550.

all but one break down. The successful megaspore is the one nearest the chalazal end of the sac, and it may be one of two, three, or four (*fig. 25*). It is very seldom that a megaspore nearer the micropyle shows any signs of reaching the fertilization period, although this doubtless happens in some cases, as is indicated by *fig. 27*, in which the megaspore nearer the micropyle has begun to develop, and is evidently the one which will reach maturity.

[5] STRASBURGER, *ibid.*

The embryo sac follows the normal order of development, and at an early stage there occurs a thickening of cells in the chalazal region adjacent to the megaspore (*fig. 26*), and this spreads until it includes the whole of the layer of integument adjacent to the nucellus (*fig. 27*). At this stage the contents of the embryo sac are rich in food material, especially starch.

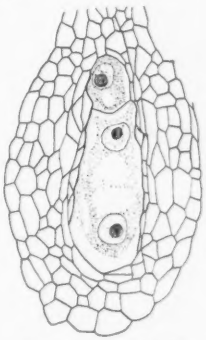


FIG. 27.—*Spiraea Japonica.* Megasporangium in which two megaspores of the same row, resulting from one division of the megaspore mother-cell, have begun to develop, with the micropylar spore ahead. × 550.

THE EMBRYO.

In reference to the embryo, it need only be said that the development is regular and normal, and that the suspensor, unlike that of the legumes, but in accordance with typical illustrations of suspensors, consists of but a single row of cells of no extraordinary size (*fig. 28*). Their purpose is evidently that of directing the food supply derived from the embryo sac, and supplied by the endosperm, which surrounds or clings to the embryo at this stage, to the embryonic root region.

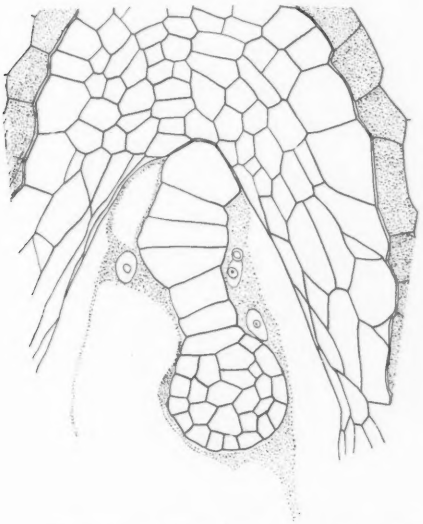


FIG. 28.—*Spiraea Japonica.* Longitudinal section through a young embryo with simple suspensor. × 550.

CONCLUSIONS.

1. The order of floral development is as follows: sepals, inner stamens, carpels, outer stamens, petals.

2. The microsporangia reach maturity before the megasporangia.

3. No archesporial cell or plate of archesporial cells is differentiated in the microsporangium.

4. The tapetum is cut off from the outside of the sporogenous mass.

5. Several archesporial cells are differentiated in the megasporangium. These cut off tapetal cells, by the divisions of which the megaspore mother-cells become deep-seated.

6. The megaspore mother-cell which is centrally located develops, and the megaspore near the chalazal end of the ovule is usually the successful one.

7. Enlargement of certain cells with thicker walls and denser staining contents takes place in the chalazal region of the nucellus as nutrition is supplied through these cells for the development of the embryo sac.

8. The development of the embryo is normal, and the suspensor is simple.

The work in preparation for this paper was done at the University of Chicago, under the direction of Professor John M. Coulter and Dr. Charles J. Chamberlain.

HULL BOTANICAL LABORATORY.

BRIEFER ARTICLES.

NOTES OF TRAVEL. IX.

A PRECOCIOUS POPLAR BRANCH.

(WITH ONE FIGURE)

In the plaza at Patras, the principal commercial port of Greece, are a number of poplar trees that have been recently planted out for shade. When I was there in March 1901, these trees were just beginning to unfold their leaves, and my attention was attracted by a remarkably precocious branch on one of them, which was so far ahead in its development that it stood out as prominently against the sky as a clump of mistletoe does on a Kentucky oak in winter. The leaves on this branch were fully developed, in fact seemed to me more luxuriant than usual, and the case was so striking that I took a kodak picture of the tree. On examining the branch somewhat closely, I found that it arose from a wound which seemed to have been produced by some wagon in its passage along the street. The wound had healed, and this most pre-

Poplar tree in Patras, Greece, with precocious branch.

cocious branch originated near the callus which had formed over it.

The importance of this curious case of precocity is its possible bearing upon the production of earlier developing varieties of shade or fruit trees. The literature may be full of references to the matter, but so far as I am aware no one has made the attempt to originate an early leafing variety of ornamental trees by wounding the branches and looking for precocious shoots from the wounds, from which to propagate by buds or cuttings. It is possible that cuttings taken from a branch originating in this way may prove no earlier than the mother plant, but there is also a possibility that the wound has led to the production of an adventive bud which has varied in the direction of precocity.

I am confident that in such cultures as the hop, where the plant has been propagated asexually for centuries, bud variation plays an important part in the formation of new strains or races; and new Citrus varieties are suspected to have originated in this way. Just how great this variation is, and how often it can be utilized, remains a question for research. The case here described seemed so striking that I thought it worthy of a short note and a photograph. There was no sign of the branch having been budded with a different variety, and, unfortunately, I do not know the species of the tree. In fact, the interest of the case only appeared to me after I was many miles away from Patras.

It would be interesting to know whether the same branch developed a second year much earlier than the other branches of the tree, *i. e.*, whether this precocity was the result of a direct but transitory stimulus of the wound, or a constant character of the bud produced near the wound.—DAVID G. FAIRCHILD, *Department of Agriculture, Washington, D. C.*

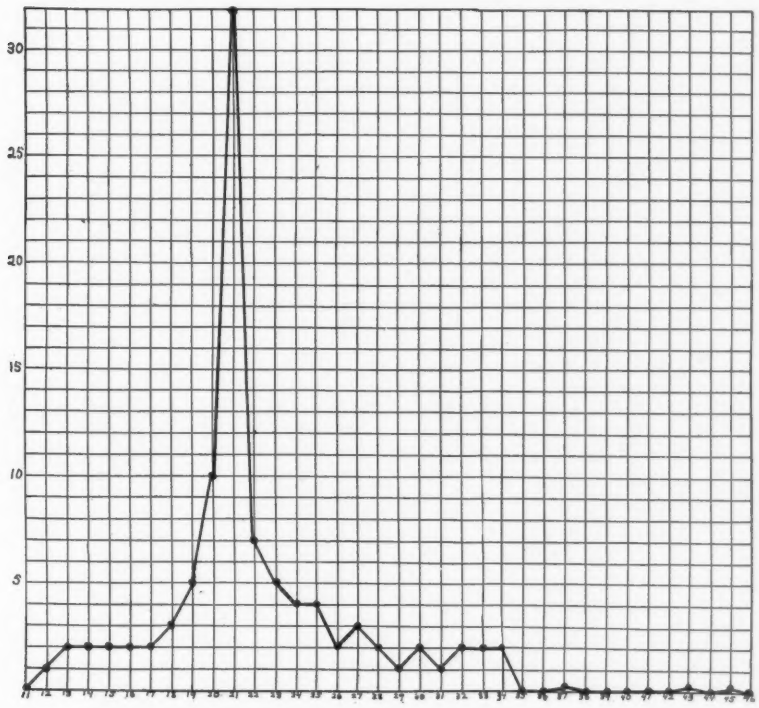
NUMERICAL VARIATION OF THE RAY FLOWERS OF COMPOSITÆ.[1]

(WITH ONE FIGURE)

THE following observations constitute a preliminary report upon the variation, both numerical and morphological, exhibited by the flowers

[1] Contributions from the Laboratory for Plant Physiology and Pathology of the Alabama Polytechnic Institute. I.

and inflorescence of the Compositæ, a subject which I have had under investigation for several years. The present paper treats only of the numerical variation found in the ray-flowers of *Helianthus annuus*. These particular studies were completed while I was connected with



Curve of variation.

the Oklahoma Agricultural and Mechanical College. I take pleasure in acknowledging my obligations to Mr. A. C. Lewis of that institution for assistance.

If we may judge from some recent utterances of botanists and zoologists, is is evident that the mathematical and statistical study of variation is destined to occupy a prominent part in the development of biological research. Dr. Robinson, in his address as retiring President of the Botanical Society of America, said, "that among the subjects which

seem to invite immediate attention the most important are: (1) the determination of the modes and degrees of variation, an investigation which alone can yield data for a more critical discrimination of plant categories."[2] Equally forceful words were spoken by Dr. Davenport in his address as retiring vice-president of Section F of the A. A. A. S. at its Denver meeting. He said[3] "the science of variation is therefore one of those that we may hope to see established in this century. I feel convinced that statistical studies are first of all necessary to lay the foundations of the science." The recent establishment of the periodical "Biometrika" will do much to increase the general interest in this department of biological investigation.

The specimens of *Helianthus annuus* selected for this study were growing on vacant lots in Stillwater, Oklahoma, forming there the typical sunflower waste-formation so characteristic of that region. Determinations of the number of ray flowers were made on a total of 1103 heads selected at random over the various vacant lots. The following tabulation and curve of variation show the results thus secured.

Class	Individuals in the class	Percentage of individuals in the class	Percentage of individuals in this or a higher class	Class	Individuals in the class	Percentage of individuals in the class	Percentage of individuals in this or a higher class
12	10	0.90	100	29	16	1.45	11.78
13	22	1.99	99.09	30	26	2.35	10.33
14	23	2.08	97.09	31	15	1.35	7.97
15	25	2.26	95.01	32	25	2.26	6.61
16	22	1.99	92.74	33	20	1.81	4.35
17	26	2.35	90.75	34	25	2.26	2.53
18	40	3.62	88.39	35	0	0	0.27
19	50	4.53	84.76	36	0	0	0.27
20	112	10.15	80.23	37	1	0.09	0.27
21	352	31.91	70.08	38	0	0	0.18
22	80	7.25	38.16	39	0	0	0.18
23	50	4.53	30.91	40	0	0	0.18
24	40	3.62	26.38	41	0	0	0.18
25	42	3.80	22.75	42	0	0	0.18
26	25	2.26	18.94	43	1	0.09	0.18
27	36	3.26	16.68	44	0	0	0.09
28	18	1.63	13.41	45	1	0.09	0.09

From the above tabulation and frequency curve the following facts are secured. The class having 21 ray flowers includes over 31 per cent. of all the individuals. Slightly over 10 per cent. of all the individuals

[2] ROBINSON, B. L., Problems and possibilities of systematic botany. Science 14:474. 1901.

[3] DAVENPORT, C. B., Zoology of the twentieth century. Science 14:319. 1901.

are segregated in classes 30 to 34 inclusive, while only 3 individuals were found having more than 34 ray flowers.

The curve shows a positive skewness of 1.1, but at present it cannot be stated whether this skewness is toward or away from the ancestral condition of the species. Seeds collected from heads having given numbers of ray flowers have been secured for breeding purposes and the study of the plants thus secured may enable us to properly interpret the skewness here observed.—E. MEAD WILCOX, *Alabama Polytechnic Institute, Auburn.*

CURRENT LITERATURE.

BOOK REVIEWS.

Plant pathology from a new standpoint.

A RECENT work by Professor H. Marshall Ward[1] places the subject of plant diseases in a new light that must prove very helpful and suggestive to students, as well as to cultivators who are able to read the work understandingly. If every one interested in the cultivation of plants were fairly well informed regarding vegetable physiology and pathology, the work could be said to be a popular treatise, for it is written from the standpoint of the plant and the plant grower, and not, as is usual, from that of the fungus or other disease agent and the mycologist. Moreover, technical terms are employed only where English equivalents are not available, or where obscurity and prolixity are to be avoided.

The work is not a manual of vegetable therapeutics, as may be judged from the fact that only ten pages are devoted to remedies; and it is not a mycological treatise, as it does not describe fungi, but when mentioning them assumes that the reader already knows them. However, it treats of the general nature of disease in plants in a broad and philosophical way. To give a deeper and truer insight into the subject, an introductory part of eighty-five pages reviews the fundamental features of normal physiology and power of adaptation, based upon the very latest researches. It is excellent reading. In this part strong blows are dealt against the persistent ignorance and misconception that falsely exalt chemistry to the first place among the sciences which aid the cultivator, that misconstrue the nature of plant food, that consider the soil an inert substance, and that fix the attention of the cultivator upon the weather and the environment, rather than upon the plant itself. In America these and kindred errors are rapidly being corrected through the influence of the Experiment Stations and Agricultural Colleges, and we have already discarded the use of some terms based upon these errors, notably the misleading word "carbon-assimilation," which the author apparently feels it his duty to cling to for the present.

The body of the book deals with such topics as health and disease, life and death, causes, nature, and symptoms of disease, the factors of an epidemic, relation of variation to disease, grafts, wounds, excrescences, exudations, and monstrosities. These and similar topics are treated with a directness

[1] WARD, H. MARSHALL, Disease in plants. 12mo, pp. xiv + 309. London: The Macmillan Company, 1901.

and depth that can be very imperfectly suggested in a brief review. No class of readers will get so much profit and satisfaction from the work as those who desire to know the latest word that science has to offer in explanation of the causes and principles underlying the phenomena of plant activity in both health and disease, and who desire the information presented in a luminous, concise manner, and so far as possible, in untechnical language.

When the point of view of the author becomes the prevalent point of view both of the public and the investigator, great advantage will accrue to all who deal with plants, and this work should be an important factor in hastening the time.—J. C. ARTHUR.

The Cyclopedia of American horticulture.

THE fourth and last volume of Bailey's *Cyclopedia of American horticulture* has just appeared.[2] The scope and quality of this great work have been spoken of in reviews of the preceding volumes.[3] The editor hopes that this Cyclopedia will never be revised, "for it is the purpose of the book to make a record of North American horticulture as it exists at the opening of the twentieth century." It is expected that subsequent progress will be recorded in a series of supplements with cumulative indexes, the manuscript for the first two of which is already prepared. Numerous important genera are presented in the usual way, notable among which are *Rosa*, *Rubus*, *Salix*, *Saxifraga*, *Sedum*, *Selaginella*, *Spiraea*, *Tulipa*, *Vitis*. These and other genera are all treated in the usual way, the synoptical keys of the cultural species being followed by descriptions of treatment, regions of cultivation, etc. The treatment of roses is especially noteworthy, the editor venturing the opinion that this subject will probably be consulted oftener than any other in the Cyclopedia. In order to make it worthy of such a place the treatment is particularly full. After the usual scientific synopsis, including fifty species, the horticultural classification is presented, followed by a discussion of the treatment of roses, their adaptation to different regions and all other points of view that might be of interest to those cultivating roses. Perhaps the most notable articles dealing with fruits are those upon the strawberry and tomato.

Aside from such papers there are noteworthy articles upon *Railroad gardening*, *Rock gardens*, *Seedage*, *Spraying*, and *Storage*. By the name *Seedage* the editor refers to the propagation of plants by seeds and spores, and after the general treatment there is a section upon *Seed breeding* by W. W. Tracy, and one upon *Seed testing* by G. H. Hicks. Under the general title

[2] BAILEY, L. H., Cyclopedia of American horticulture, etc. Vol. IV. R–Z. 4to, pp. xxx + 1487–2016, *figs. 2060–2800*, *pls. 32–50*. New York: The Macmillan Company. 1902. $5.

[3] BOT. GAZ. **29**: 282; **30**: 277; **31**: 436.

Storage, presented by the editor, there is an account of *Cold storage* by L. C. Corbet, and of *Refrigerator cars* by J. H. Hale.

Aside from the taxonomic presentation of many genera, perhaps the most interesting articles to botanists are *Teratology*, presented by C. R. Barnes; *Trees*, presented in all their aspects by various writers; and *Winter protection*, described and illustrated by W. C. Egan and B. M. Watson.

Professor Bailey is to be congratulated upon the completion of this work, especially upon the peculiar features it possesses in comparison with the ordinary cyclopedias dealing with horticultural material. Its chief features, as they stand out in the mind of the editor, are that it represents a living horticulture, rather than a compilation of odds and ends selected from other encyclopedias; that it contains synoptical keys that enable the reader to name the species; that the leading articles are signed and represent the contributions of more than 450 persons; and that throughout the whole presentation one detects no rigid conception of plant, forms, but feels the drift of an evolutionary motive. That such a work should have been begun, so far as actual writing is concerned, in January 1899, and the last proof read December 31, 1901, speaks well for the organizing power and the capacity for work of its editor and his staff. The statistics show that the total number of entries is 4357; the number of genera described is 2255; the number of species fully described is 8793, of which 2419 are native to North America north of Mexico.—J. M. C.

Physiology in the laboratory.

TO STUDY the plant in action is to become acquainted with the most interesting phase of the science of botany. It is a part of the subject that appeals especially to the young student. But to make intelligent progress, to look into the more recondite processes without elaborate apparatus, and to proceed without undue loss of time and check to enthusiasm requires a good guidebook. Even under an excellent instructor a handbook is advantageous. A work that meets the requirements for a laboratory manual of physiology for the beginner has recently been issued from the press of Longmans, Green & Co., prepared by Dr. Daniel T. MacDougal,[4] director of the laboratories of the New York Botanical Garden.

The work is perspicuous, concise, up to date, and requires only simple apparatus, easily obtained by most colleges and high schools, and in part no apparatus at all. The whole ground of physiology is covered: growth and growth movements, reproduction and germination, movements of gases and liquids, nutrition of green plants, parasites and saprophytes, respiration, digestion, stimulation, and correlation.

The text is more than a set of directions for performing experiments, for

[4] MACDOUGAL, DANIEL TREMBLY, Elementary plant physiology. New York: Longmans, Green & Co. 1902. 12mo, pp. xi+138, with 108 text cuts.

it gives a readable account of many topics, and incidentally furnishes much information upon the general subject of physiology. The cuts are especially serviceable in showing how the student is to proceed. In short, the work comes as near as possible to the perfect manual, which tells enough to be helpful and attractive, and yet leaves the student to ascertain the actual facts for the most part by his own observations upon the living plant or in introductory demonstrations.

The work is all the more satisfactory for being the outgrowth of two preliminary works, the first published in 1894 and the second in 1895, both now out of print.—J. C. ARTHUR.

MINOR NOTICES.

THE SECOND FASCICLE of Ohio fungi, distributed by Professor W. A. Kellerman, of Columbus, O., has been issued, and is larger than the preceding one. It contains twenty-six numbers, of which seven belong to the genus Puccinia, five to Uromyces, three to Ustilago, two each to Gymnoconia and Gymnosporangium, and one each to Aecidium, Gloeosporium, Melampsora, Piggotia, Polystictus, Stereum, and Urocystis. The excellent preparation and fullness of material is maintained. The first fascicle was described in the March number of this journal (p. 239). Although these fascicles are intended for distribution to working mycologists, the author has consented to sell a very limited number at one dollar each.—J. C. ARTHUR.

THE SECOND EDITION[5] of Frost's *Laboratory guide in elementary bacteriology* (8vo) is much more convenient in form than the first (4to) edition.[6] It combines the features of a laboratory outline and of a notebook, blank pages and diagrams being inserted for records of the student's observations. The author recognizes the desirability of uniformity in cultural methods, and gives in addition to the ordinary laboratory methods of preparation of culture media those recommended by the committee on methods of the American Public Health Association. Part I is devoted to general bacteriology, with introductory chapters on morphology, physiology, and taxonomy. In the latter a number of valuable descriptive adjectives, similar to those suggested by Chester, are introduced. Part II deals with medical bacteriology, with appended chapters on animal inoculation and the examination of pathological tissues and fluids. In connection with each exercise are references for the student, both to the principal texts and to original articles on the subject under consideration. The guide is admirably planned and will form a welcome aid in the teaching of bacteriology.—E. E. IRONS.

[5] FROST, WILLIAM DODGE, A laboratory guide in elementary bacteriology. Second revised edition, pp. x + 355. Madison, Wis.: Published by the author. 1902.

[6] See review in BOT. GAZ. 31 : 439. 1901.

DR. HOLLRUNG[7] has just published his third annual report on plant pathology. This report does not differ in its essential features from the two that have preceded it. The work covers the ground that has been done along the various lines of plant pathology in different countries during the year 1900, and is divided into a general and a special part. The general part brings together (1) the progress made in the organization of plant protection, (2) the laws and ordinances relating to the protection of plants, and (3) the relation of plant diseases to the weather, methods of the dissemination of diseases, the influence of diseased plants upon man and other animals, etc. The special part of the report embraces the work done in 1900 in determining the causes of plant diseases and the means of combating them. The causes of plant diseases are considered, first from the standpoint of injuries from various sources without reference to the host plant, and second the causes of injury to different host plants. Under the former subdivision mention is made of destructive animals, such as field mice and marmots, and the means employed in destroying them; of injurious insects, their development and their control; and of weeds and the means used for their destruction. Under the second subdivision the host plants considered are grains, fodder, sugar beets, white potatoes, sweet potatoes, pod fruits, truck crops, garden products, seed and stone fruits, berries, grapes, timber, tropical plants, and ornamentals. The natural methods of combating plant diseases embrace the work done on birds, insects, fungi, and bacteria injurious to plants; while the artificial methods cover the advances made in the construction of spraying machines, as well as in the preparation of insecticides and fungicides, including powders, liquids, and gases. The report covers about 176 pages, the major portion being devoted to the special part. This is followed by about 90 pages of references to bulletins and papers, subdivided in accordance with the general plan of the work and arranged alphabetically with respect to the names of the authors mentioned under each subdivision. The work closes with a complete index, giving the names of the authors, host plants, insects, fungi, etc., thus making a very satisfactory work of reference. Dr. Hollrung seems to have been very desirous of citing everything published along all lines treated in this report, and considering the great diversity of subjects, together with the wide geographical area covered, it is surprising, and at the same time a matter for congratulation, that the work has been so carefully and so thoroughly performed in every way. In bringing out this report in such a satisfactory manner, Dr. Hollrung has rendered valuable service to all workers along the various lines of plant diseases, and it is to be hoped that he will receive sufficient encouragement to enable him to continue the good work.

[7] HOLLRUNG, DR. M., Jahresberichte ueber die Neuerungen und Leistungen auf dem Gebiete des Pflanzenschutzes. Das Jahr 1900. Pp. viii + 291. Berlin: Paul Parey. 1902. *M* 10.

He closes his preface to this third report with an earnest request that all parties actively engaged in any work relating to plant pathology would forward him separates of their published articles.—C. O. TOWNSEND.

NOTES FOR STUDENTS.

PROTOPLASMIC CONNECTIONS in a large number of plants belonging to all groups from algae to flowering plants have been studied recently by Keinitz-Gerloff.[8] Previous investigations have already made it seem probable that protoplasmic connections are universally present in the spermatophytes; the present work shows that the connections are as uniformly present in the lower groups, the filamentous algae perhaps being an exception. In such algae, however, each cell is so independent in nutrition and reproduction that the absence of connections need not occasion surprise. The suggestion is made that the connections may not be derived wholly from the *Hautschicht*, but that they may have a core of trophoplasm surrounded by *Hautschicht*. The theory that the connections conduct stimuli and materials is supported, but the reviewer believes that the whole subject needs further investigation.—CHARLES J. CHAMBERLAIN.

THE PHYSIOLOGY of adjustment to poisons dissolved in the medium has been made the subject of a contribution by Pulst.[9] He worked with the Mucor, Aspergillus, Botrytis, and Penicillium. The effect of a number of kations was determined, among them Cu, Zn, Hg, Ni, Co, Cd, Pb, etc. The anion SO_4 was usually used, but some others (*e. g.*, $C_4H_4O_6$, CN, NO_3, Cl, etc.) also appear in the tables. Penicillium withstands a much higher concentration of these substances than do the other three moulds. The effect of a salt upon the plant appears to depend in great measure upon the electrical charge of the kation, also in part upon the action of undissociated molecules. As was known before, a gradual increase in concentration brings about an accommodation to much stronger solutions than could be withstood if the change were made suddenly. Copper ions appear to be unable to penetrate the protoplast of Penicillium, though the other protoplasts studied are readily permeable to them.—B. E. LIVINGSTON.

ACCORDING TO SHIBATA,[10] the fertilization of the egg and polar nuclei of *Monotropa uniflora* is practically the same as has been observed in all the forms in which double fertilization is known. The sperms are elongated when they enter the embryo sac, and become more nearly spherical as fusion progresses.

[8] Neue Studien über Plasmodesmen. Ber. Deutsch. Bot. Gesell. **20**: 93–117. *pl. 4.* 1902.

[9] PULST, C., Die Widerstandsfähigkeit einiger Schimmelpilze gegen Metallgifte. Jahrb. Wiss. Bot. **37**: 205–263. 1902.

[10] SHIBATA, K., Die Doppelbefruchtung bei *Monotropa uniflora* L. Flora **90**: 61–66. 1902.

The second male cell comes in contact with the upper polar nucleus, while the lower polar nucleus comes in contact with the male cell and upper polar nucleus and the three fuse simultaneously. The endosperm nucleus divides before the oospore shows signs of division. Only in Naias, as reported by Guignard, does the oospore divide first, but even here, when division of the endosperm begins, it proceeds with much greater rapidity than in the embryo. The two deeply staining bodies reported by the reviewer in the end of the pollen tubes of Silphium and Erigeron were observed and figured in Monotropa, but their origin was not determined. The article is illustrated with ten excellent figures. — W. J. G. LAND.

HAUPT [11] adds somewhat to our knowledge of gland action by a recent paper from the Leipzig laboratory. Working with extrafloral nectaries, he finds that the secretion of sugar begins at a certain age of the nectary and with relatively high atmospheric humidity, *i. e.*, with checked transpiration. After it is started, a rise in humidity increases the amount of water excretion, but that of sugar remains constant. Usually when secretion is stopped, the already secreted sugar fails to be resorbed, but in some cases resorption occurs. In Vicia and certain Euphorbiaceae the red and yellow rays of the sun's spectrum are necessary for the secretion of sugar, and the secretion is resorbed in darkness, or in blue and violet light. Plants deprived of CO_2 exhibit the light reaction even after many days; thus the response is not connected with the photosynthetic process. There exists in all plants experimented upon a minimum temperature for the beginning of secretion, but after the process has begun it goes on slowly even somewhat below this minimum.— B. E. LIVINGSTON.

THE EMBRYOLOGY of the Araliaceae has just been described at some length by Ducamp.[12] He finds, as a rule, only one archesporial cell in the nucellus of the ovule. This cell gives rise to a tapetal cell and the megaspore mother cell. The mother cell may develop directly into the embryo sac, or may first give rise to an axial row of three or four megaspores, the lowest of which usually germinates, although one of the middle cells occasionally develops at the expense of those above and below. In *Fatsia Japonica* a case is figured in which the middle cell of an axial row of three had divided longitudinally. In another case, after the mother cell had divided transversely, both daughter cells had divided longitudinally. A case in which two mother cells in a single nucellus had divided in this manner gives the nucellus a very sporangium-like character, and in the opinion of the writer strengthens the

[11] HAUPT, HUGO, Zur Secretionsmechanik der extrafloralen Nektarien. Flora **90**: 1–41. 1902.

[12] DUCAMP, L., Recherches sur l'embryogénie des Araliacees. Ann. Sci. Nat. Bot. VIII. **15**: 311–402. *pls. 6–13*. 1902.

theory that the nucellus is the homologue of the sporangium of the cryptogams. The statement is made that the division of the nucellus of the mother cell sometimes takes place without the formation of cell walls, but the figures are very small and may bear another interpretation. Double fertilization was looked for, but nothing definite was found. The development of the embryo and the appearance of tissue systems are described in detail.—CHARLES J. CHAMBERLAIN.

ITEMS OF TAXONOMIC INTEREST are as follows: C. V. PIPER (Bull. Torr. Bot. Club **29**: 221–226. 1902), in his sixth paper entitled "New and noteworthy northwestern plants," describes new species of Antennaria (2), Madia, Synthyris, Astragalus, and Philadelphus.—J. C. ARTHUR (*idem* 227–231), in his second paper entitled "New species of Uredineae," describes new species of Uromyces (2), Puccinia (4), and Uredo (2).— P. A. RYDBERG *idem* 232–246), in his eighth paper entitled "Studies on the Rocky mountain flora," describes new species of Stanleya (2), Thelypodium (2), Lepidium (2), Roripa (3), Lesquerella, Physaria, Cardamine, Sophia (2), Draba (7), Geranium (2), Oxalis, and Lupinus (4).—ALICE EASTWOOD (Proc. Calif. Acad. Sci. III. Bot. **2**: 241–252. *pls. 23–24.* 1902) has published nine new species of Ribes from the Pacific coast, and also a key to the 57 species of that region.—C. D. BEADLE (Biltmore Bot. Studies **1**: 51–137. 1902) has published 104 new species of Crataegus from the southeastern states.— F. E. BOYNTON (*idem* 138–142) has published new southern species of Amorpha (2) and Coreopsis (2).—T. G. HARBISON (*idem* 158) has published a new Trillium from Alabama.—C. D. BEADLE (*idem* 159–163) has published new southern species of Philadelphus (3) and Prunus (2).— Dr. WEBER (Bull. Soc. Nat. d'Acclim. de France, May 1902), in his second paper entitled "Études sur les Opuntia," has discussed *O. leucotricha*, the "duraznillo" of the Mexicans, and also the six other species of the section CRINIFERA, one of them (*O. Gosseliniana*) being new.— E. L. GREENE (Ottawa Nat. **16**: 35–39. 1902) has described new northwestern species of Actaea (3), Delphinium, Cerastium (3), Carduus, Erigeron (2), Pentstemon, and Lappula.—J. M. C.

PROFESSOR F. O. BOWER[13] has called attention to the imperfect sporangia of pteridophytes, notably those at the base and apex of the strobili of lycopods, in which group 94 species were examined. In certain forms there is no line of demarcation between the strobilus and the vegetative part of the plant, any leaf being a potential sporophyll. The other extreme is to be found where the strobilus is made up of sporophylls whose form and arrangement differ from the foliage leaves. All degrees of transitional stages exist. In all species quite constantly abortive or imperfect sporangia were found at the base, apex, or in sterile zones of the strobilus. The author discusses these

[13] Imperfect sporangia in certain pteridophytes. Are they vestigial? Annals of Botany **15**: 225–267. 1901.

incompletely developed sporangia "in order that these facts may have their true weight in the general discussion of vegetative and fertile regions of the primitive leafy sporophyte." It is possible to look upon an imperfectly developed part as either upon the up-grade (nascent) or on the down-grade (evanescent) of development. These terms "nascent" and "evanescent" may be applied to either the ontogeny or the phylogeny. As an advocate of the antithetic theory of alternation of generations, Professor Bower does not accept the recapitulation theory. Hence the question of priority in the history of descent cannot be settled summarily by the sequence in the ontogeny. Neither an infinite number of transitional forms, nor experimentally the conversion of a sporophyll into a foliage leaf proves anything more than an intimate relationship between the two. It in no way settles phylogenetic priority.

A clue, the writer urges, may be obtained from the bryophytes. A comparison of the most primitive sporangium (Riccia) with more complex types indicates the intercalation of a seta before the spores are formed, and leads one to conclude that the seta does not precede spore development phylogenetically, but that in more complex capsules the spore development is retarded by an intercalated stage; in short, progressive sterilization and intercalation of vegetative parts takes place to provide for the growing demand for nutrition. In the genus Lycopodium a comparison of closely related forms and a study of the individual part has led the author to believe that the history of development is analagous to that of the bryophytes. By progressive sterilization the basal sporangia have become functionless and vestigial. The incomplete sporangia at the apex of the cone he regards as supernumerary, not in the same category with those at the base. Selaginella, Isoetes, and Equisetum are also discussed from the same standpoint. The author concludes that although abortive parts are less common in plants than in animals, and have played a less important rôle in theories of plant morphology than in zoology, they should not be left out of account altogether.—FLORENCE M. LYON.

F. E. LLOYD has filled an important gap in our knowledge of the essential morphology of angiosperms by his studies on the Rubiaceae. The first part, dealing chiefly with *Vaillantia hispida*, was issued August 26, 1899, and was noted in this journal.[14] The second part[15] now issued deals with numerous other forms, so that the conclusions are derived from a study of twenty-three species representing nine genera of Rubiaceae. In all forms, excepting species of Houstonia, the nucellus is very much reduced, not being distinguishable except at early stages, when it is a cap-like layer of cells covering the archesporium. As usual among the Sympetalae, the very small nucellus is

[14] BOT. GAZ. **29**: 292. 1900.

[15] LLOYD, FRANCIS E., The comparative embryology of the Rubiaceae. Mem. Torr. Bot. Club **8**: 27–112. *pls. 8–15*. 1902.

associated with a massive integument. In Houstonia the ovules have no integument, the archesporium becoming deeply imbedded by growth of the nucellar tissue. In the Spermacoceae an outgrowth derived from the funiculus is described as a "strophiole," and contains the vascular supply of the ovule. Throughout all the forms the archesporium contains seven to fifteen cells, the larger numbers occurring among the Galieae. Each spore mother cell forms the usual tetrad of four megaspores in linear series, but rarely are there any walls. In some cases two or more megaspores begin to function, sometimes in the same tetrad; ordinarily, however, the innermost megaspore of a central tetrad finally becomes the single embryo sac. The behavior of the embryo sac among the Galieae and in Diodia is quite remarkable, since it breaks through the nucellar cap and passes into the micropyle. The antipodals give evidence of more or less activity, among some of the forms one enlarging decidedly; among others division occurring so that there are four to ten antipodals; while in other forms they are ephemeral. Among the Galieae there is a remarkable suspensor, the cells elongating laterally or lateral branches arising and penetrating among the endosperm cells. It is another very interesting illustration of the various forms of haustorial development in connection with the embryo.

In the first division of the mother cell the spindle is multipolar in origin, and no centrosomes are to be found. In Crucianella and Asperula, whose cytological features were carefully studied, the reduced number of chromosomes is ten and twelve respectively; but after counting a large number of cases the writer believes that the number is not constant. In Asperula, in a late anaphase of the first division, the second longitudinal splitting of the chromosomes is already quite evident. In Crucianella this splitting takes place in the telophase. After the first division the daughter nuclei pass into a somewhat incomplete resting stage, no nucleolus being formed, and the nuclear membrane being quite indistinct. This division is heterotypic, but the second division, and also the divisions that occur during the germination of the megaspore, are homotypic. Judged from a cytological standpoint, the divisions which give rise to the row of four cells are true tetrad divisions, and the four cells are spores.

The memoir closes with a description of the behavior of the pollen tube in Diodia and Richardsonia, special stress being laid upon the determination of the course of the pollen tube.— J. M. C.

PROFESSOR GOEBEL has certainly earned the thanks of all students of evolution, and specifically of hybrids and plant-breeding, by reprinting the remarkable paper of Gregor Mendel on "Versuche über Pflanzen-hybriden.[16]

[16] Flora **89**: 364–403. 1901. In a note of historical interest, Dr. Goebel states that the paper presented in 1865 and published in 1866 was long unknown to botanists. DeVries, Correns, and others made the re-discovery and pointed out its great value. It is now even more accessible, having found a place in Ostwald's "Klassiker der exakten Wissenschaften" as No. 121, published by Wilhelm Engelmann, 1901.

Artificial pollination to produce variations in color and the striking regularities that appeared in hybrid forms from the same crosses were the special features of Mendel's work, which had for its object a study of the development of hybrids in their offspring. Mendel is not surprised at the new discovery of a generally valid law for the formation and development of hybrids, considering the great difficulties involved. No previous work, as he points out, was carried on in such a manner as to allow of the determination of the number of the different forms in which the offspring of hybrids appear, and to show that these forms can be classified with certainty in the several generations and the mutual numerical conditions determined; although such comprehensive study is the only way finally to solve a question which, in the evolution of organic forms, is of no mean importance.

The reasons for selecting the genus Pisum are given, and from thirty-four varieties of peas twenty-two were selected for the experiments, after a two-year test had shown them to be constant in their offspring. To study the changes in the inheritance of different characteristics, and to determine the law according to which these differences appear in the succeeding generations, were the objects of the experiment, and the latter object would constantly divide itself into as many experiments as there were constant different characteristics in the plants selected. Of such characteristics there were studied: the differences in the shape of the ripe seed; differences in the color of the endosperm, and in the color of the seed coats; differences in the form of the ripe pods and the color of the unripe pods; differences in the position of the flowers, and finally differences in the length of the axes.

Earlier experiments had shown that hybrids[17] were not, as a rule, exact averages of the parents. Often certain prominent characteristics appeared to such an extent that another characteristic would be rare or even absent. This was the case with the Pisum species. Mendel classifies such characteristics as dominating and recessive ("dominirende und recessive"). All experiments showed that it was immaterial whether the dominating characteristic was in the seed parent or in the pollen parent. Of the differing characteristics, the following were dominant: (1) the round or roundish seed with or without shallow depressions; (2) the yellow color of the endosperm; (3) the gray, gray-brown, or leather-brown color of the seed-coat, in combination with a violet reddish flower and reddish spots in the leaf axils; (4) the simple domed form of the pod; (5) the green color of the unripe pods in combination with the green color of the stems, the ribs of the leaves, and the calyx; (6) the distribution of flowers along the stems; (7) the length of the longer axis.

The first generation of hybrids, in addition to the dominating characteristics, showed also the recessive characteristics in their peculiarities, and in

[17] Hybrids (Hybriden) is used in the paper in the sense of "cross."

the decisively apparent average of 3:1, *i. e.* of four plants of this first generation three had the dominating and one the recessive character. This was true without exception for all characters which were considered. Intermediate forms were not noticed in any of the experiments. As an example may be mentioned that in the first experiment, from 253 hybrids 7324 seeds were had in the second year. Of these, 5474 were round or roundish, and 1850 were angular and wrinkled, resulting in a ratio of 2.96:1. In the second experiment, 258 plants gave 8023 seeds, of which 6022 were yellow, and 2001 green, giving a ratio of 3.01:1. The other ratios were for (3) 3.15:1, (4) 2.95:1, (5) 2.82:1, (6) 3.14:1, (7) 2.84:1. For the whole series the ratio was 2.98:1, or practically 3:1.

The second generation showed that these forms, which in the first generation had exhibited the recessive character, did not vary in this character. They remained constant or fixed. Of those with the dominant characteristic in the first generation, two parts gave offspring which in the ratio of 3:1 carry the dominant and recessive characteristics, *i. e.* the same relation as the hybrid forms; and only one part remained constant with the dominant characteristics. In the first experiment of this series, 565 plants from round seeds of the first generation gave 193 with none but round seeds — and were therefore constant in this characteristic, — 372 gave round and angular seeds in the ratio of 3:1. The number of hybrids was therefore to the number of constants as 1.93:1. In the second experiment the relations were 3:1 and 2.13:1. In the succeeding experiments the number of plants was reduced, but the ratios as a whole remained constant, although showing greater variations.

The ratio 3:1 in the first generation becomes for all the experiments 2:1:1, distinguishing the dominating characteristic both as an original and a hybrid character. As the members of the first generation come directly from the seed of the hybrids, it is now seen that the hybrids of each two differing characteristics gave seed of which one-half again developed the hybrid character, while the other gave plants which remained constant and exhibited in equal parts the dominating and recessive character.

The first and second experiments carried through six generations, the third and seventh through five, and the fourth, fifth, and sixth, through four generations, show the ratio of 2:1:1, although beginning with the third generation only a small number of plants was used. If, then, A represent one of two constant characteristics, *e. g.* the dominating one, the recessive designated by a, and Aa the hybrid form in which both characteristics are united, there results the expression $A+2Aa+a$ for the developmental series of the offspring of hybrids with two differing characteristics. The tendency of hybrids to revert to the parental type is explained by this expression. In the case of two and three differing characteristics, it was found that the hybrids were closer to such parents as had the greater number of dominating characteristics. Designating the seed parent by AB, the pollen parent by ab, the

round seed by A, the angular seed by a, the yellow endosperm by B, and the green endosperm by b, then the relations as found by experiment were expressed by the term $AB+Ab+aB+ab+2ABb+2aBb+2AaB+2Aab+4AaBb$, or a combination of $A+2Aa+a$ and $B+2Bb+b$. For three differing characteristics the combination was $A+2Aa+a$, $B+2Bb+b$, $C+2Cc+c$.

With some further experiments, Mendel then concludes that the offspring of hybrids, in which several essentially different characteristics are united, are the members of a series of combinations in which each two differing characteristics are combined in a developmental series. This at the same time proves that the behavior of two differing characteristics in hybrid combination is independent of other variations in the two parents. Developing his mathematics still further, he shows that if n designate the number of characteristic differences in the two parent plants, then 3^n is the number of the terms in the combination, 4^n the number of the individuals, and 2^n the number of the combinations that remain constant. The foregoing results led to attempts at experimental proof of the theory that the ovary of the hybrid contains as many germ cells and the anthers as many pollen cells as constant forms of combination are possible. This was shown for peas, as indicated in the results.

Experiments with *Phaseolus vulgaris* and *P. nanus* gave results corresponding to those already mentioned, but only partially corroborative results were had with *Phaseolus nanus* as seed parent and *P. multiflorus* as pollen parent. In this latter experiment the changing color caused some interesting observations and speculations on the theory of this change in accordance with the results developed in other experiments.

The concluding pages deal with the work of Kölreuter and Gärtner, especially along the lines of Mendel's experiments, and finally with a discussion of the changing of one variety into another by means of artificial pollination.—G. N. LAUMAN.

NEWS.

THOMAS COMBER, the well-known English botanist, died at Blackpool, January 24.

DR. B. M. DUGGAR, of the Bureau of Plant Industry, has been elected Professor of Botany at the University of Missouri.

DR. A. JAKOWATZ has been appointed Assistant at the Botanical Museum and Garden of the University of Vienna.

THE ADVISERS IN BOTANY for the Carnegie Institution are F. V. Coville, N. L. Britton, Gifford Pinchot, and J. M. Macfarlane.

ACCORDING TO *Science*, 83,000 acres of forest land have been purchased by the State Forestry Commission in central Pennsylvania.

THE DEGREE OF LL.D. has been conferred upon B. T. Galloway, Director of the Bureau of Plant Industry, by the University of Missouri.

A NEW EDITION of Oliver's translation of Kerner's *Pflanzenleben* is announced by Blackie & Son, London, at a considerably reduced price.

A BIOGRAPHICAL SKETCH of Lewis D. von Schweinitz, with a portrait, written by C. L. Shear, is published in the March number of *Plant World*.

DR. OLIVER R. WILLIS, the editor and reviser of Alphonso Wood's botanical texts, died April 27, at White Plains, N. Y., at the age of 87 years.

ERNST A. BESSEY, of the Bureau of Plant Industry, will sail early in July to secure seeds of forage plants and cereals in Russia, the Caucasus, and Turkestan.

A BIOGRAPHICAL SKETCH of the late Alfred W. Bennett, written by J. G. Baker, and accompanied by a portrait, is published in the April number of *Jour. Roy. Micr. Soc.*

PROFESSOR A. ZIMMERMANN, until recently at Buitenzorg, has been appointed botanist at the biological station at Amani, Post station Tanga, Dutch East Africa. He was to reach his station about the middle of April.

IN *Malpighia* (**15**: 297–324. 1902) there are published the memorial addresses delivered January 5 last in connection with the establishment of the bust of Giuseppe Gibelli, formerly of the Botanical Institute of Torino. The chief speaker was Professor R. Pirotta, of the Royal Botanical Institute of Rome.

THE BOTANICAL SOCIETY OF AMERICA will hold its eighth annual meeting at Pittsburg, Pa., June 30 to July 2, under the presidency of Dr. J. C. Arthur. The business sessions will be held in the Hotel Schenley, and the

program of scientific papers will be given in Phipps' Botanical Hall, beginning at 11 A. M., July 1.

THE INCREASING OPPORTUNITIES for the investigator at the Royal Botanic Garden, Peradeniya, Ceylon, become apparent in the recent annual report of Director J. C. Willis. During 1901, in addition to visits for administrative purposes, W. H. Lang and A. G. Tansley secured important results and material at the garden.

THE BILL AUTHORIZING the establishment of a biological station on the Great Lakes by the Commissioner of Fish and Fisheries has passed the Senate. The selection of a suitable site involves an investigation of the claims of eight states, and for this purpose, as well as to secure the necessary land and water rights, an appropriation of $10,000 has been made.

G. S. JENMAN, Government Botanist of British Guiana, died at Georgetown February 28. His previous position (1873–1879) was superintendent of the botanical garden at Castleton, Jamaica. He was especially familiar with the ferns of British tropical America, and at the time of his death was publishing a conspectus of them in parts, five of which had appeared.

DURING THE YEAR 1901 accessions to the herbaria of the New York Botanical Garden amounted to 55,747 sheets, representing 77,657 specimens. In the various plantations and conservatories the number of species in cultivation was as follows: public conservatories 3344, herbaceous grounds 3012, fructicetum 512, arboretum 169, pinetum 16, salicetum 43, viticetum 65.

DR. B. E. LIVINGSTON and MR. H. N. WHITFORD, Assistants in Botany, and MR. C. D. HOWE, Fellow in Botany, of the University of Chicago, have been appointed collaborators in the Bureau of Forestry, Department of Agriculture, for the year beginning July 1, 1902. Dr. Livingston will work on some forest problems in the northern part of the southern peninsula of Michigan; Mr. Whitford will continue some investigations already begun in the forests of the Rocky mountains in the northwestern part of Montana; and Mr. Howe will do similar work in the vicinity of Burlington, Vermont.

THE THIRD REPORT (1901) of the Michigan Academy of Science contains the following botanical papers: Transition from stem to root in *Echinocystis lobata*, by J. B. POLLOCK; Ecological study of a glacial lake near Ann Arbor (abstract), by H. S. REED; A disease of the white birch, by JOHN LARSEN; Interfoliar scales of monocotyledonous aquatics (abstract), by MINNA C. DENTON; Notes on the flora of Eaton co., by H. L. CLARK; Forests of northern Michigan (abstract), by W. J. BEAL; A noteworthy occurrence of Wolffia, and Notes on *Utricularia cornuta*, by C. A. DAVIS; Notes on Michigan saprophytic fungi, New species of Michigan fungi, and A sclerotium disease of the huckleberry, by B. O. LONGYEAR; Causes inducing asparagus to take its form of growth, by L. LENORE CONOVER.

GENERAL INDEX.

The most important classified entries will be found under Contributors, Personals, and Reviews. New names and names of new genera, species, and varieties, are printed in **bold-face type**; synonyms in *italics*.

A

A. A. A. S., Pittsburg meeting 320
Absorption of water and solutes 392
Acer 386; dasycarpum 377
Achillea millefolium 294
Aconitum 392; delphinifolium 140
Actaea 473
Adamovic, Lujo, personal 87
Alaska, plants of Nome City 126, 199, 284
Albescence, Laurent on 77; of leaves 76
Allen, C. E., personal 87
Allium cepa 80
Alopecurus alpinus 130
Alsine, longifolia 69; longipes 69; **validus** 69
Alternaria, **citri** 234; tenuis 235
Ames, Mrs. M. L. P., death of 319
Amorpha 473
Amsinckia tesselata, seedling of 152
Amygdalin, effect on Botrytis 430
Andrews, D. A., work of 73
Andrews, F. M., personal 319
Andromeda, polifolia 209; *tetragona* 209
Androsace, Chamaejasme 211; septentrionalis 299
Anemone 392; narcissiflora **uniflora** 141; parviflora 141; Richardsoni 142
Annals of Botany, index 174
Annals of the Royal Botanic Gardens, Peradeniya 173
Antennaria 473; alpina 295; *serotinum* 130
Anthocyan and synthesis 82
Antirrhinum, and copper compounds 31
Aquilegia 392
Araliaceae, Ducamp on embryology of 472
Araucaria excelsa 159
Arbacia pustulosa, fertilization of 166
Arbutus *alpina* 209
Arcterica 78
Arctogrostis latifolia 130
Arctostaphylos alpina 209
Arenaria, arctica 137; lateriflora 138; macrocarpa 138; physodes 138; Rossii 139
Argemone 392
Aristolochia arborea 256; *maxima* 256; pilosa **ligulifera** 256; **securidata** 256
Arker, work of 75
Armeria vulgaris 213
Arnica 316; obtusifolia 295
Arnoldi, work of 98, 168
Árpád, Degen, personal 248
Artemisia, borealis 299; Norvegica Pacifica 296; Tilesii 296
Arthrotaxis, morphology of 168
Arthur, J. C., 62, 239, 466, 468, 469; personal 479; work of 241, 473
Asclepias, pollen mother cell 390
Ashe, W. W. 230
Aspergillus, and copper solutions 39, 74; flavus and copper compounds 31; niger, Korinski on respiration of 241, osmotic pressure of 166
Aster 316; **arcticus** 295; prereginus 295; variation in 390
Asteranthe 385
Astragalus 473; alpinus 204; *leucanthus* 206
Atolls, origin of 446
Atragene 392
Atriplex Lampa 155
Aulotandra 316
Autumn foliage in Europe 376
Azalea *Lapponica* 210; *procumbens* 210

B

Bacteria, nodules 389; producing warts 240
Bacteriology, chair of 398; laboratory guide 469
Bailey, W. W., personal 172
Bailey L. H., "Cyclopedia of American horticulture" 467
Bain, S. M. 245
Baker, J. G., personal 479; "conjugating yeast" 72
Bamboo, Shibata on reserve food 312
Baranetsky, J., work of 394
Barbour, personal 320

Barnes, C. R. 163, 240, 312, 313, 381, 383, 385, 386; personal 88, 319
Bartholomew, Elam, personal 86
Barton, Edith, personal 87
Basidiomycetes, binucleate cells in 1
Beadle, C. D., work of 473
Beal, W. J., personal 480
Beauverie, work of 75
Behrens, work of 73
Beihefte zum Botanisches Centralblatt 247
Belli, C. S., personal 398
Benecke, work of 74
Bennett, A. W., death of 247; sketch of 479; work of 391
Berlese, A. N., personal 399
Bernard, work of 75
Bessey, C. E. 157; personal 174, 319
Bessey, E. A. 84, 387; personal 479
Betula nana 135
Bevan, E. J. (and Cross, C. F.); "Researches on cellulose" 163
Bicuculla 392
Biological laboratory, Cold Spring Harbor 319
Biological Station, on Great Lakes 480; University of Montana 247
Bisetaria 391
Bitter, Georg, personal 247
Blackman, work of 164
Blaisdell, F. E., Alaskan plants of 126, 199, 284
Bogue, E. E,, personal 88
Bonnier, work of 83
Bordeaux mixture 26, 41, 43
Bornet, personal 175
Botanical Garden, of Missouri 175; of New York 173
B. A. A. S. 398
Botanical Society of America 479
Botanisches Centralblatt 175
Botanists of the central states, Chicago meeting 87
Botrytis, and copper solutions 39; cinerea, parasitism of 421; vulgaris and copper compounds 31
Bouilhac, work of 83
Bower, F. O., work of 473
Boynton. F. E., work of 473
Brachythecium 316
Branch growth, direction of 394
Branner, J. C., personal 398
Brannon, M. A. personal 87
Brassica oleracea, Molisch on albescent 77
Bravaisia **grandiflora** 255
Brefeld, work of 5
Brewer, W. H., personal 319
Britton, Mrs. E. G., personal 320
Britton, N. L., personal 246, 399, 479; work of 391
Brodiaea capitata, subterranean organs 416
Bromelin 313
Bromus pacificus 130
Brotherus, V. F., work of 239
Bruneis, Stephen, personal 320
Bryologist 320
Bryophytes, Tansley and Chick on conducting tissue in 76
Buller, A. H. R., personal 87
Bulletin de l'Herbier 247
Bulletin de l'Herbier Boissier, card index 240
Burrill, T. J., personal 87
Büsgen, personal 172
Butomus umbeliatus, ovules of 214

C

Cacalia, ovata 157; **sulcata** 157
Cakile and decomposition of NaCl, Benecke on 74
Caldwell, O. W., personal 87
Callisia *grandiflora* 261
Calochortus 241; umbellatus, subterranean organs 415
Campanula, lasiocarpa 285; uniflora 285
Campbell, D. H., personal 86, 172
Campylospermum 391
Carbohydrates, autumnal migration 73; Griffon on synthesis of 82
Carbon dioxid, influence of, on form and structure 82
Cardamine 473; bellidifolia 146; **Blaisdellii** 146; pratensis 146, 147; purpurea 146, 147
Cardiocarpon anomalum 170
Cardot, J., work of 315
Carduus 473
Carex, capitata 130; compacta 130; lagopina 130; macrochaeta 130; misandra 130; rigida 130; scirpoides 130
Carices, Fernald on 388
Cassiope tetragona 209
Castanea pumila 108
Castilleia pallida 299
Cavara, F., personal 398
Cellulose 163
Centralbl. Bakt. Parasit. Infekt. 175
Centrosome in Polytoma 241
Cephalotaxus Fortunei, pollen tube of 94
Cerastium 473; alpinum Fischerianum 139; *Fischerianum* 139; vulgatum 139
Ceratozamia longifolia, male gametophyte of 91; pollen tube of 94
Cestrum, nocturnum 254; **Poasanum** 253

Chaetomium, and copper compounds 31
Chamaecrista 316
Chamaecyparis 444
Chamberlain, C. J. 165, 168, 310, 317, 390, 395, 471, 472; personal 85, 86
Chesnut, V. K., work of 163
Chick, work of 76
Chlorogalum Pomeridianum, subterranean organs 412
Chlorophyll, and carbohydrate synthesis 82; in Nostoc, Bouilhac on 83
Chlorophyceae 78
Chodat, R., work of 315
Chorioactis 392
Chrysanthemum integrifolium 296
Chrysosplenium tetrandrum 199
Church, Arthur H., work of 387
Cineraria frigida 297
Citation, rules for 398
Citharexylum **pterocladum** 255
Cladochytrium, Alismatis 49; Butomi 50; Menyanthis 58
Clark, H. L., personal 480
Clark, Judson F. 26, 245; work of 244
Claytonia, **sarmentosa** 137; tuberosa 137
Clematis 392
Clements, F. E., personal 87
Clinton, G. P. 49
Clintonia Andrewsiana, subterranean organs 401
Clute, W. N.: "Our ferns in their haunts" 70
Cochlearia officinalis 147
Cockerell, T. D. A. 378; work of 241
Coker, W. C. 89
Collections of A. H. Curtiss 154
Colmeiro, Miguel, death of 85
Columnea **calcarata** 254
Comarum palustris 202
Comber, Thomas, death of 479
Commelina, nudiflora 261; Virginica 261
Compositæ, variation of ray flowers 462
Conard, Henry S., work of 389
Concilium Bibliographicum, botanical bibliography 320
Conducting tissue in Bryophytes 76
Conioselinum Gmelini 299
Coniothyrium diplodiella 84
Conn, H. W.: "Agricultural bacteriology" 309
Conocephalus, Haberlandt's new organ on 300
Conover, Lenore, personal 480
Contributors: Arthur, J. C. 62, 239, 466 468, 469; Ashe, W. W. 230; Bain, S. M. 245; Barnes, C. R. 163, 240, 312, 313, 381, 383, 385, 386; Bessey, C. E. 157; Bessey, E. A. 84, 387; Chamberlain, C. J. 165, 168, 310, 317, 390, 395, 471, 472; Clark, J. F. 26, 245; Clinton, G. P. 49; Cockerell, T. D. A. 378; Coker, W. C. 89; Copeland, E. B. 74, 164, 242, 300; Coulter, J. M. 71, 72, 73, 78, 163, 239, 241, 315, 384, 385, 386, 387, 389, 390, 391, 392, 467, 473, 474; Cowles, H. C. 70, 71, 73, 74, 75, 76, 77, 79, 82, 84, 160, 164, 236, 240, 311, 314; Davis, B. M. 241, 242, 313, 314, 315, 386; Eastwood, Alice 126, 199, 284; Fairchild, D. G. 376, 461; Fernald, M. L. 154; Frye, T. C. 165; Gooding, L. N. 66; Hall, J. G. 214; Harper, R. A. 1; Holton, Nina G. 243; Irons, E. E. 469; Land, W. J. G. 74, 241, 471; Lauman, G. N. 397, 475; Leavitt, R. G. 376; Livingston, B. E. 166, 380, 392, 471, 472; Lyon, Florence M. 164, 171, 473; Newcombe, F. C. 177, 263, 341; Overton, J. B. 363; Pierce, N. B. 235; Preston, C. E. 150; Rimbach, A. 401; Russell, H. L. 309; Sargent, C. S. 108; Schneider, A. 162; Schrenk, H. von 388; Shaw, C. H. 437; Shear, C. L. 220; Smith, J. D. 249; Smith, R. E. 421; Timberlake, H. G. 80; Townsend, C. O. 470; Webb, J. E. 451; Whitford, H. N. 313, 316; Wilcox, E. M. 462; Wrightson, P. G. 393
Copeland, E. B. 74, 164, 242, 300; personal 85, 88, 246
Copper compounds, toxic properties of 26
Coprinus 27; clamps in 5; ephemerus 18; micaceus and copper compounds 31; radiatus 18, uninucleated cells 3; stercorarius 19
Coptis trifolia 142
Coreopsis 473
Cornu, Maxime, death of 400
Cornus, canadensis 209; suecica 209
Corydalis pauciflora 145
Costantin, M. J., personal 246
Costus **splendens** 260
Coulter, J. M. 71, 72, 73, 78, 163, 239, 241, 315, 384, 385, 386, 387, 389, 390, 391, 392, 467, 473, 474; personal, 86, 88, 172
Coulter, J. G. personal 85
Coulter, S. M. personal 319, 400
Coulter, Stanley, personal 87
Coville, personal 479, work of 78, 316
Cowles, H. C. 70, 71, 73, 74, 75, 76, 77, 79, 82, 84, 160, 164, 236, 240, 311, 314; personal 88, 173, 320, 399, 400; work of 316
Cramer, Carl E., death of 246
Crataegus 473; altrix 232; apiifolia 124; berberifolia 111; **blanda** 121; **Bushii**

109; canadensis 233; **cibilis** 232; collina 115; **corusca** 117; Crus-galli 110; **edita** 110; elliptica 113; **Ellwangeriana** 118; **fecunda** 111; flava 123; *flava* 124; **Floridana** 124; **gemmosa** 119; **Georgiana** 113; **lacera** 123; mollis 116, 234; **obtecta** 233; ovalifolia 113; prunifolia 113; **Ravenelii** 122; **sera** 115; **sordida** 114; tomentosa 121; viridis 122
Cross, C. F. (and Bevans, E. J.): "Researches on cellulose" 163
Cryptomeria, morphology of 168
Cuba, Harvard Station 399
Cummings, Clara E., personal 399
Cunninghamia, morphology of 168
Cupresseae, male gametophyte of 91
Cupressus funebris 159
Currant cane blight and copper compounds 31
Curtiss, A. H., collections of 154
Cuspidatula 77
Cyanophyceae 317
Cycladenia 316
Cyphochlaena 78
Cystosira barbata, fertilization of 166
Czapek, Fr., personal 246; work of 73

D

Dale, Elizabeth, work of 389
Dalla Torre, C. G. (and Harms, A.): "List of genera" 239
Dandeno, J. B., work of 393
Davenport, C. B., personal 400
Davis, B. M. 241, 242, 313, 314, 315, 386; personal 85, 88, 320
Davis, C. A., personal 480
Davis, N. F., personal 319
Debray, Ferdinand, personal 176
Delphinium 392, 473; **Blaisdellii** 142; Californian species of 241; Menziesii 143
Densmore, H. G., personal 87
Denton, Minna C., personal 480
DeVries, Hugo: "Mutation theory" 236
Diapensia lapponica 211
Diaporthe, stromata of 10
Didymoon nudiflorum 261
Diels, work of 74
Dipteris, Seward and Dale on 389
Diseases, grape rot 84; onion smut, 84
Doassansia alismatis 60
Dodecatheon frigidum 211
Donnellia 261; **grandiflora** 261
Dörfler's "Botaniker Adressbuch" 385; work of 385
Double fertilization, in Monotropa uniflora 471; in Naias major, Guignard on 74; in Ranunculaceae 388
Draba 473; alpina 148; hirta 148; hirta **tenella** 148
Dryas, integrifolia 202; octopetala 202
Dryer, Charles R.: "Lessons in physical geography" 71
Dryopteris fragrans 129
Ducamp, work of 472
Dufft, Karl, death of 400
Duggar, B. M., personal 479
Durand, personal 85

E

Earle, F. S., personal 399
Eastwood, Alice 126, 199, 284; work of 241, 316, 473
Echinus microtuberculatus, fertilization of 166
Effront, J.: "Enzymes and their applications" 381
Elymus mollis 130
Embryo sac, of Araliaceae 472; of Limnocharis 214; of Rubiaceae 474; of Spiraea 459
Embryo, of Araliaceae 472; of Limnocharis 214; of Rubiaceae 474; of Spiraea 459
Empetrum nigrum 207
Engler, A., work of 78, 385, 386: "African monographs" 385; "Pflanzenreich" 71, 239, 386; (and Drude) "Vegetation der Erde" 247, 311; (and Prantl) "Natürlichen Pflanzenfamilien" 239
Enzymes 381; formation of 243; of Nepenthes, Vines on 313
Ephedra, male gametophyte of 91
Epiblepharis 391
Epilobium, latifolium 208; spicatum 208
Epiphegus, subterranean plants of 376
Equisetum, pratense 129; variegatum 129
Erigeron 473; uniflorus 296
Eriophorum, angustifolium 130; vaginatum 130
Erodium, cicutarium 152, seedling of 150
Erythronium, grandiflorum 67; Hendersoni 67; **obtusatum** 67; **parviflorum** 67
Escluse, Charles de l', work of 386
Etard, work of 82
Euphrasia 77
Eurhynchium 316
Evolution, Korschinsky on 396
Excretion of water and solutes 392

F

Fairchild, D. G. 376, 461; personal 86

Farmer, J. Bretland, personal 87
Farwell, O. A.: work of 384; "Catalogue of Detroit flora" 384
Fernald, M. L. 154; work of 388
Fernow, B. E., personal 398
Ferns, Underwood on 390
Fertilization, in Pythium, 314; in Arbacia pustulosa 166; in Cystosira barbata 166; in Echinus microtuberculatus 166
Field, H. H., personal 320
Filix, fragilis 129; montana 129
Fimbristylis schoenoides 154
Fink, Bruce, personal 87
Fischer, A., personal 246; work of 80
Fisher, W. R., personal 246
Flahault, personal 398
Florida, plants of 154
Flower of Spiraea 451
Forest reserves 320
Forester 172
Forestry and irrigation 172
Franchet, personal 176
Frank, A. B., death of 400
Fraxinus, **catawbiensis** 230; biltmoreana 230; profunda 230
Friedel, work of 315
Fritillaria 316; lanceolata, subterranean organs of 403
Frost: "Laboratory guide" 469
Fruhwirth, work of 73
Frye, T. C., 165; personal 88; work of 390
Fujii, K., personal 86
Fumaria *pauciflora* 145
Fungi of Ohio, Kellerman on 469
Fungicides, action of 244
Fusarium Solani, Bernard on 75

G

Gager, C. S., work of 390
Gagnepain, F., work of 316
Galenia, secunda 155; boreale 293
Galloway, B. T., personal 479
Gametophyte, of Helminthostachys 392; of Ophioglossum 392; of Schizaea 392
Ganong, W. F., personal 173, 174
Gardiner, work of 79
Generic nomenclature 220
Gentiana 77; frigida 284; glauca 284; propinqua 285
Geopyxis 392
Georgia, plants of 154
Gepp, Anthony, personal 87
Geranium 473
Gerloff, Kienitz, work of 79
Germination, relation of light 164
Geum Rossii 203
Giesenhagen: "Niphobolus" 71
Gifford, John, personal 173
Gilbert, J. H., personal 173
Giovannozzi, work of 240
Gland action 472
Glaziocharis 384, 391
Gloeosporium malicorticis and copper compounds 31
Glyptostrobus, morphology of 168
Gnaphalium 316
Goebel, work of 475
Going, Maud: "With the wild flowers" 70
Goldflus, M., work of 84
Gomont, M., work of 78
Gonzalea **bracteosa** 252
Goodding, L. N. 66
Gray, George M., personal 400
Green, J. R., personal 246, 398
Greene, Edward L.: work of 315, 391, 473; "Plantae Bakerianae" 72
Greenland, botanical exploration 398
Grey, R. M., personal 399
Griffiths, David, work of 388
Griffon, work of 82
Groom, Percy, personal 246
Grover, F. O., personal 88
Growth, affected by various salts, air currents, osmotic pressure 75
Guarea, purpurea 250; **Tuerckheimi** 250
Guatemala, undescribed plants from 249
Guignard, L., work of 74, 388
Gurania **megistantha** 251
Guttulinopsis 239
Gymnandra *Stelleri* 293
Gymnopteris triangularis 129
Gymnosperms, morphology of 89, 168

H

Haberlandt, W., work of 300, 313
Halacsy, E., work of 385; "Flora of Greece" 385
Hall, John G. 214
Hallowell, S. M., personal 246
Halsted, B. D., personal 174, 399
Harbison, T. G., work of 473
Harper, R. A. 1; personal 87
Harrimanella 78
Harris, Mrs., personal 320
Harshberger, J. W., personal 86
Hartig, Robert, death of 85
Hattori, W., work of 74
Haupt, work of 472
Heald, F. D., personal 87
Hedysarum, **auriculatum** 205; truncatum 205, 206
Hegler, Robert, death of 400; work of 317

Helianthus annuus, variation in ray flowers 463
Heliotropium, curassavicum 378; **xerophilum** 379
Helleborus trifolius 142
Helminthostachys zeylanica, prothallia of 392
Hemming, Ernest, personal 173
Heracleum lanatum 208
Herbarium of New York Botanical Garden 480
Hesperaster 241, 392
Heterogenesis, Korschinsky on 396
Hicks, J. F., work of 84
Hill, E. J., personal 88
Hill, T. G., personal 174
Hillhouse, W., translation of Strasburger's "Practical botany" 310
Hirn, personal 176
Holferty, G. M. personal 88
Hollick, Arthur, personal 173
Hollrung: "Jahresbericht" 470
Holm, Theo, work of 77
Holton, Nina G. 243
Horticulture, Cyclopedia of American 467
Hottes, C. F., personal 87
Howe, C. D., personal 88, 480
Huber, Jakob: "Arboretum Amazonicum" 72
Huntington, Anna Oakes: "Studies of trees in winter" 162
Hyacinthus orientalis 80
Hybrids, Gregor Mendel on 475
Hydathodes, Lepeschkin on function of 164; substitute 300
Hydnoraceae 71
Hymenomycetes, binucleate cells in 1
Hypholoma 27; appendiculata and copper compounds 31
Hypochnus, binucleated cells of 4

I

Ikeno, work of 97, 242
Ilex decidua **Curtissii** 155
Indians, Chesnut on plants used by 163
Iris, **arctica** 132; Missouriensis 68; **pelogonus** 68; setosa 132
Irons, E. E., 469
Isaria pulcherrima, protobasidia in 20
Istvanffi, G., work of 386; "Code de l'Escluse" 386

J

Jack, J. B., death of 247
Jackson, B. Daydon, personal 87
Jackson, J. R., personal 247
Jakowatz, A., personal 479
Jenman, G. S., death of 480
Johnson, D. S., personal 319
Jönsson, Helgi, work of 77, 82
Journal of geography 173
Jumelle, work of 82
Juncoides, campestre sudeticum 130; parviflorum 130
Juncus, castaneus 130; Haenkei 130

K

Károly, A. F., personal 248
Karyokinesis in Magnolia and Liriodendron 73
Keinitz-Gerloff, work of 471
Kellerman, W. A., personal 173, 239; work of 469
Kerner's "Pflanzenleben," translation of 479
Klebs, work of 242
Klinge, J. C., death of 398
Knowlton, F. H., personal 398
Koernicke, Max, personal 319
Korschinsky, S. I., death of 400; work of 396; "Heterogenesis und Evolution" 238
Korsinski, I., work of 241
Krasser, Friedrich, personal 246
Kruuse, personal 398
Kuntze, Otto, personal 174
Kupfer, Elsie M., work of 392
Kusano, work of 313

L

Laestedia Bidwellii 84
Lagotis glauca 293
Lájos, Thaisz, personal 248
Lamson-Scribner, personal 86
Land, W. J. G., 74, 241, 471; personal 88
Lang, W. H., personal 87; work of 392
Lappula 473
Larsen, John, personal 480
Lathrop, Bryan, personal 86
Lathyrus maritimus 299
Lauman, G. N. 397, 475
Laurent, work of 77
Lawson, A. A., personal 399
Leathers, W. S., personal 400
Leaves, albescence of 76; Blackman and Matthaei on responses to traumatic stimulation 164; Linsbauer on transparency of 83; Thomas on subterranean 78
Leavitt, R. G., 376; "Outlines of botany" 382
Lechea Leggettii 155

Ledum palustris 210
Lepeschkin, W., work of 164
Lepidium 473
Lepidocarpon 169
Lesquerella 473
Leucanthemum *integrifolium* 296
Lexicon Generum Phanerogamarum 174
Light, indirect action on stem and leaf 81; influence of different luminous rays on form and structure 81; Schulz on relations to germination of spores 164
Liliaceae, subterranean organs of 401
Lilium Pardalinum, subterranean organs of 404
Limnorchis 78
Limnocharis emarginata, embryo sac and embryo of 214
Limnaea borealis 294
Linsbauer, work of 83
Livingston, B. E., 166, 380, 392, 471, 472; personal 88, 480
Lloyd, G. E., work of 474
Lloydia, *alpina* 130; serotina 130
Loisleuria procumbens 210
Long, W. H. Jr., work of 316
Longyear, B. O., personal 480
Lotsy, J. P., personal 175
Lubbock, work of 150
Lupinus 473
Lychnis apetala 140
Lycopodium, alpinum 129; annotinum 129; Selago 129
Lycopods, imperfect sporangia 473
Lyman, G. H., personal 87
Lyon, Florence M. 164, 171, 473; personal 88
Lyon, H. L., work of 165
Lysimachia vulgaris 79
Lythrum, **Curtissii** 155; lanceolatum 155

M

Macbride, T. H., personal 87
MacDougal, D. T., personal 86, 172, 246, 399; "Elementary plant physiology" 468
Macfarlane, John, personal 172, 479
MacMillan, Conway, personal 87, 248
Madia 473
Mágócsy-Dietz, Sandor, personal 172
Magyar Botanikai Lopok 248
Maire, R., work of 1
Marine Biological Laboratory 400
Marsilia, **oligospora** 66; vestita 66
Massee, George, personal 87
Matayba, **clavelligera** 250; floribunda 251
Mathews, Mary E., personal 88
Matruchot, personal 176
Matthaei, work of 164
Mayaca, *Aubletii* 154; Aubletii 154; fluviatilis 154; *Michauxii* 154
Mayenburg, O. H., work of 166
Maze, personal 176
McRae, Miss L. G., personal 320
Meehan, S. M., personal 173
Meehan, Thomas, personal 85
Megasporangium of Spiraea 457
Meiocarpidium 385
Mendel, Gregor, on hybrids 475
Merckia *physodes* 138
Merrell, E. D., personal 319
Mertensia, **Alaskana** 287; maritima 299; paniculata 287; strigosa 287
Microsporangium of Spiraea 454
Microscope, apparatus for focusing projecting 241
Miehe, Hugo, work of 80
Millspaugh, C. F., personal 88
Mirande, personal 176
Mitchell, J. N., personal 87
Mitosis, in Polytoma 240; Wisselingh on Spirogyra 315
Miyoshi, M., work of 46
Molisch, work of 77
Moll, J. W., work of 241
Molliard, personal 176
Mollinedia, Boliviensis 258; **Costaricensis** 257
Monoon Virginicum 261
Monotropa 316; uniflora, Shibata on double fertilization in 471
Montia sarmentosa 137
Moore, A. C., personal 320
Moore, G. T., personal 86, 87, 320
Moore, R. A., work of 387
Moraines, vegetation in 437
Mottier, D. M., personal 87
Movements, Giovannozzi on hygroscopic 240
Mucor spinosus and copper compounds 31
Mueller, a monument to Baron Sir F. von 246
Mutation theory 236
Myosotis, *alpestris* 288; *aretioides* 288; sylvatica alpestris 288

N

Naias, conferta 154; major, Guignard on double fertilization in 74
National irrigation 172
Naturalists of the Central States, Chicago meeting 86
Neger, F. W., personal 246
Nelumbo lutea, Lyon on cotyledon of 165

Nepenthes, enzyme of 313
Nepenthin 313
New Phytologist 248
Newcombe, F. C. 177, 263, 341; personal 88
Nicholson, George, personal 247
Nome City, plants of 126, 199, 284
Nuclei, in Cyanophyceae 317; migration of 80
Nymphaea, Conard on 389

O

Oat smut 387
Ocotea, dendrodaphnis 259; **Palmana** 258; **Quisara** 259; Veragnensis 259
Oedocephalum, and copper solutions 39; albidum 34, and copper compounds 31
Ohio fungi 469; exsiccati 173, 239
Olive, E. W., work of 239
Oliver, F. W., work of 389
Omphalodes nana 288
Ophioglossum pendulum, prothallia of 392
Opuntia 473
Oranges, rot of 234
Orthocarpus 316
Osborn, Raymond, personal 248
Osmotic pressure, Beauverie on 75, in fungus hyphae 166
Osterhout, G. E., work of 78, 392
Ostreopsis 78
Ouratea, gigantophylla 249; podogyna 249; **Tuerckheimii** 249
Overton, J. B. 363; personal 87; work of 77, 83
Oxalis 473
Oxytropis, leucantha 206; Mertensiana 206
Oxyria digyna 135

P

Palladin, W. J., personal 87
Pallavicinia, Tansley and Chick on tracheids of 76
Palmer, Edward, personal 174
Papain 313
Parasitism of Botrytis cinerea 421
Papaver 392; nudicaule 145; radicatum 145
Pardo de Tavera, T. H.: "Medicinal plants of the Philippines" 162
Parish, S. B., work of 77
Parnassia, Kotzebuei 199; palustris 199
Parrya macrocarpa 148
Parthenogenesis, in Alchemilla 369; in Antennaria 368; in Thalictrum purpurascens 363
Pathology, plant 466, 470
Patterson, Flora A., personal 400
Pavetta indica, warts on 240
Peck, Charles H., work of 316, 384
Pedicularis, capitata, 288, 289; **hians** 289, 290; hirsuta 290; lanata 291; Langsdorffii 291; Sudetica 290, 291, 292; verticillata 292
Penhallow, D. P., personal 86
Penicillium, and copper 74; glaucum and copper compounds 31
Pentstemon 473
Peperomia 391
Peradeniya Botanic Garden 480
Perilla ocymoides 156
Personals: Adamovic, Lujo 87; Allen, C. E. 87; Ames, Mrs. M. L. P. 319; Andrews, F. M. 319; Árpád, Degen 248; Arthur, J. C. 479; Bailey, W. W. 172; Baker, J. G. 479; Barbour, 320; Barnes, C. R. 88, 319; Bartholomew, Elam 86; Barton, Edith 87; Beal, W. J. 480; Belli, C. S. 398; Bennett, A. W. 247, 479; Berlese, A. N. 399; Bessey, C. E. 174, 319; Bessey, E. A. 479; Bitter, Georg 247; Bogue, E. E. 88; Bornet, 175; Branner, J. C. 398; Brannon, M. A. 87; Brewer, W. H. 319; Britton, E. G. 320; Britton, N. L. 246, 399, 479; Bruneis, Stephen 320; Buller, A. H. R. 87; Burrill, T. J. 87; Büsgen, 172; Caldwell, O. W. 87; Campbell, D. H. 86, 172; Cavara, F. 398; Chamberlain, C. J. 85, 86; Clark, H. L. 480; Clements, F. E. 87; Colmeiro, Miguel 85; Comber, Thomas 479; Conover, Lenore 480; Copeland, E. B. 85, 88, 246; Cornu, M. 400; Costantin, M. J. 246; Coulter, J. M. 86, 88, 172; Coulter, J. G. 85; Coulter, S. M. 319, 400; Coulter, Stanley 87; Coville, F. V. 479; Cowles, H. C. 88, 173, 320, 399, 400; Cramer, C. E. 246; Cummings, C. E. 399; Czapek, F. 246; Davenport, C. B. 400; Davis, B. M. 85, 88, 320; Davis, C. A., 480; Davis, N. F. 319; Debray, F. 176; Densmore, H. G. 87; Denton, M. C. 480; Dufft, K. 400; Duggar, B. M. 479; Durand, 85; Earle, F. S. 399; Fairchild, D. G. 86; Farmer, J. B. 87; Fernow, B. E. 398; Field, H. H. 320; Fink, B. 87; Fischer, A. 246; Fisher, W. R. 246; Flahault, 398; Franchet, 176; Frank, A. B. 400; Frye, T. C. 88; Fujii, K. 86; Galloway, B. T. 479; Ganong, W. F. 173, 174; Gepp, A. 87; Gifford, J. 173; Gilbert, J. H. 173; Gray, G. M. 400; Green, J. R. 246, 398; Grey, R. M. 399; Groom,

P. 246; Grover, F. O. 88; Hallowell, S. M. 246; Halsted, B. D. 174, 399; Harper, R. A. 87; Harris, Mrs. 320; Harshberger, J. W. 86; Hartig, R. 85; Heald, F. D. 87; Hegler, R. 400; Hemming, E. 173; Hill, E. J. 88; Hill, T. G. 174; Hirn 176; Holferty, G. M. 88; Hollick, A. 173; Hottes, C. F. 87; Howe, C. D. 88, 480; Jack, J. B. 247; Jackson, B. D. 87; Jackson, J. R. 247; Jakowatz, A. 479; Jenman, G. S. 480; Johnson, D. S. 319; Karoly, A. F. 248; Kellerman, W. A. 173, 239; Klinge, J. C. 398; Knowlton, F. H. 398; Koernicke, M. 319; Korschinsky, S. I. 400; Krasser, F. 246; Kruuse 398; Kuntze, O. 174; Lajos, T. 248; Lamson-Scribner, F. 86; Land, W. J. G. 88; Lang, W. H. 87; Larsen, J. 480; Lathrop, B. 86; Lawson, A. A. 399; Leathers, W. S. 400; Livingston, B. E. 88, 480; Longyear, B. O. 480; Lotsy, J. P. 175; Lyman, G. H. 87; Lyon, F. M. 88; Macbride, T. H. 87; MacDougal, D. T. 86, 172, 246, 399; Macfarlane, J. 172, 479; MacMillan, C. 87, 248; Mágócsy-Dietz, S. 172; Massee, G. 87; Mathews, M. E. 88; Matruchot 176; Maze 176; McRae, L. G. 320; Meehan, S. M. 173; Meehan, T. 85; Merrell, E. D. 319; Millspaugh, C. F. 88; Mirande 176; Mitchell, J. N. 87; Molliard 176; Moore, A. C. 320; Moore, G. T. 86, 87, 320; Mottier, D. M. 87; Neger, F. W. 246; Newcombe, F. C. 88; Nicholson, G. 247; Osborn, R. 248; Overton, J. B. 87; Palladin, W. J. 87; Palmer, E. 174; Patterson, F. A. 400; Penhallow, D. P. 86; Philippi, R. A. 172; Pinchot, G. 479; Pirotta, R. 479; Poirault, G. 398; Pollock, J. B. 88, 480; Post, T. von 174; Ramaley, F. 87; Reed, H. S. 88, 480; Robertson, C. 87; Robinson, B. L. 172; Rowlee, W. W. 173; Rumphius, G. E. 174; Sadebeck R. 85; Saint-Yves 176; Schimper. A. F. W. 160, 400; Schneider, A. 88; Schoch-Etzensperger, E. 320; Schrenk, H. von 86; Schewinitz, L. D. 479; Scott, D. H. 87; Shaw, C. H. 320; Shear, C. L. 479; Shull, G. H. 88, 319; Smith, Mrs. A. M. 320; Smith, B. H. 86; Smith, E. F. 85, 398; Snow, L. M. 88; Spalding, V. M. 173, 319; Spillman, W. J. 247, 319; Stoklasa, J. 247; Tansley A. G. 248; Thom, C. 87; Thornber, J. J. 87; Tilden, J. E. 85, 248; Timberlake, H. G. 87; Tracy, S. M. 400; Trelease, W. 86, 87, 172; True, R. H. 320; Tubeuf, K. von 319; Uhlworm, O. 87; Umbach, L. M. 87; Vines, S. H. 87; Vladesco 247; Warming, E. 85; Westgate, J. M. 88; Wettstein 85; Wheeler, C. F. 88; Whitford, H. N. 88, 247, 399, 480; Wilcox, E. M. 88; Willis, J. C. 480; Willis, O. R. 479; Winkler, H. 247; Wolfe, J. J. 320; Yendo, K. 248; Yocum, G. M. 88; Zacharias, E. 399; Zimmerman, A. 479.

Petasites frigida 297

Pethybridge, work of 75

Pfeffer's: "Pflanzenphysiologie" 380

Phegopteris phegopteris 129

Philadelphus 473

Philippi, R. A., personal 172

Photosynthesis, gas exchanges apart from the living plant 315

Phyllostachys mitis 312

Phyllotaxis, relation to mechanical laws 387

Physaria 473

Physiology in the laboratory 468

Physoderma *maculare* 59

Pick, work of 82

Pierce, N. B., 235

Pilacrella delectans 21

Pinchot, Gifford, personal 479

Pine cone, morphology of 157

Pinguicula, **arctica** 293; vulgaris 293

Pinus, Laricio 99, pollen tube of 94; Pumilio 159; silvestris 97

Piper **calophyllum** 257

Piper, C. V., work of 473

Piperia 78

Pirotta, R., personal 479

Plantago fastigiata, self-burial of seeds 388

Plasmodesmen 79

Pluchea Quitoc 157

Poa, alpina 130; arctica 130

Podocarpus, affinities of 102; archegonia 98; coriacea 89; embryo 99; female prothallium 96; gametophytes and embryo 89; pollen grain 90; pollen sac 90; pollen tube 94

Poepalanthus pilulifer 154

Poirault, G., personal 398

Poisons, Pulst on physiology of adjustment 471

Polarity, Miehe on change in 80

Polemonium, acutiflorum 286; caeruleum 286

Pollard, C. L., work of 318

Pollen mother cells, karyokinesis in 73

Pollen of Zostera 165

Pollock, J. B., personal 88, 480

Polyembryony, in Limnocharis 217
Polygonum 391
Polygonum, bistortoides 135; viviparum 136
Polypodium, **Alfari** 262; capillare 262
Polytrichum, Tansley and Chick on anatomy of 76
Pond islands, origin of 446
Poplar, a precocious branch of 461
Post, T. von, personal 174
Potamogeton 391
Potato, relation to fungus 75
Potentilla 316; biflora 203; fruticosa 203; uniflora 203
Potonié, H., work of 239
Preston, Carleton E. 150
Primula, eximia 212; Mistassinica 212; nivalis 212
Prosartes Hookeri, subterranean organs of 402
Proteids, autumnal migration 73
Prothallia, of Helminthostachys 392; of Ophioglossum 392
Protoplasm, continuity of 471; Haberlandt on longitudinal fibrils in 313; Strasburger on continuity of 79
Prowazek, work of 241
Prunus 473; Laurocerasus 164; **tarda** 108; umbellata 109
Psychotria **polyphlebia** 253
Pteridophytes, Bower on imperfect sporangia of 473
Puccinia 316, 473
Pulst, work of 471
Purdy, Carl, work of 241
Pythium, fertilization in 314

Q

Quercus rubra 377

R

Rafflesiaceae 71
Ramaley, F., personal 87
Ranunculaceae, double fertilization in 388
Ranunculus 391, 392; affinis 144; nivalis 143; Pallasii 299; pygmaeus 143; **verticillatus** 144
Reed, H. S., personal 88, 480
Rendle, A. B., work of 239
Reproduction, Klebs on physiology of 242
Reserve food in bamboo 312
Respiration of Aspergillus 241
Reviews: Bailey's "Cyclopedia of American horticulture" 467; Baker's "Conjugating yeast" 72; Clute's "Our ferns in their haunts" 70; Conn's "Agricultural bacteriology" 309; Cross and Bevan's "Researches on cellulose" 163; Dalla Torre and Harms's "List of genera" 239; DeVries's "Mutation theory" 236; Dörfler's "Botaniker Adressbuch" 385; Dryer's "Lessons in physical geography" 71; Effront's "Enzymes and their applications" 381; Engler's "African monographs" 385, "Pflanzenreich," 71, 239, 386, (and Drude) "Vegetation der Erde" 311, (and Prantl) "Natürlichen Pflanzenfamilien" 239; Farwell's "Catalogue of Detroit flora" 384; Frost's "Laboratory guide" 469; Giesenhagen's "Niphobolus" 71; Going's "With the wild flowers" 70; Greene's "Plantae Bakerianae" 72; Halácsy's "Flora of Greece" 385; Hillhouse's translation of Strasburger's "Practical botany" 310; Hollrung's "Jahresberichte" 470; Huber's "Arboretum Amazonicum" 72; Huntington's "Studies of trees in winter" 162; Istvanffi's "Code de l'Escluse" 386; Korschinsky's "Heterogenesis und Evolution" 238; Leavitt's "Outlines of botany" 382; MacDougal's "Elementary plant physiology" 468; Pardo de Tavera's "Medicinal plants of the Philippines" 162; Pfeffer's "Pflanzenphysiologie" 380; Strasburger's "Das kleine botanische Practicum" 310; Thome's "Flora von Deutschland" 71, 385; Urban's "Symbolae Antillanae" 384; Ward's "Disease in plants" 466; Warming's "Podostemaceae" 71; Wiesner's "Die Rohstoffe des Pflanzenreiches" 386; Wright's "Flowers and ferns in their haunts" 70.
Rheinbold, Th., work of 78
Rheotropism, geotropic counter curve 278; in older plants 351; latent period and after-effect 271; location of sensitive area 341; nature of stimulus 354; of roots 177, 263, 341; persistence of sensitiveness 276
Rhizoctonia and copper compounds 31
Rhizophyton 58
Rhizopus nigricans 34, and copper compounds 31.
Rhodiola *rosea* 149
Rhododendron Lapponicum 210
Ribes 473; aureum 316; lentum 316
Rimbach, A. 401
Robertson, Charles, personal 87
Robinson, B. L., personal 172; work of 77, 391

Rocks, influence on vegetation 316
Rodrigue, work of 76
Roots, rheotropism of 177, 263, 341
Roripa 473
Rosenberg, O., work of 165
Rosenvinge, work of 1
Rot, grape 84: of oranges 234
Rowlee, W. W., personal 173
Rubiaceae, bacterial nodules 389; embryology of 474
Rubus, arcticus grandiflorus 204; Chamaemorus 204
Rumex, Acetosa 136; occidentalis nanus 136
Rumphius, Georg Eberhard, personal 174
Russell, H. L. 309
Rusts, heteroecious 62
Rydberg, P. A., work of 78, 391, 473

S

Sabbatia, calycosa 156; chloroides 156; **foliosa** 155
Saccharomyces and copper compounds 31
Sadebeck, Richard, personal 85; work of 239
Saint-Yves, personal 176
Salicin, effect on Botrytis 430
Salicornia and decomposition of NaCl, Benecke on 74
Salix, alaxensis 133; Chamissonis 133; glauca 133; phlebophylla 134; reticulata 134; *speciosa* 133
Sammelzellen 56
Sanguisorba media 204
Sapium biglandulosum lanceolatum 155
Sargent, Charles S. 108
Saussurea alpina 297
Savastana alpina 130
Saxifraga, adscendens 200; bronchialis 200; comosa 200; flagellaris 200; hieracifolia 201; Hirculis 201; oppositifolia 201; punctata 201; Richardsoniana 202; rivularis 201; *stellaris comosa* 200
Schimper, A. F. W., death of 400; sketch of 160; "Pflanzengeographie" 246
Schizaea bifida, prothallium of 392
Schmidt, Johs., work of 78
Schneider, Albert 162; personal 88
Schoch-Etzensperger, Emil, personal 320
Schrenk, Herman von 388; personal 86
Schulz, N., work of 164
Schweinitz, Lewis D. von, sketch of 479
Sciadopitys, morphology of 168
Scoliopus Bigelovii, subterranean organs of 405
Scott, D. H., personal 87; work of 169
Scutellaria, **glabriuscula** 156; integrifolia 156
Seaside Laboratory, Hopkins 399; Minnesota 248
Sedum, Rhodiola 149; *roseum* 149
Seedlings, of Erodium and Amsinckia, Lubbock on 150; rheotropism in 183
Selby, A. D., work of 84
Selaginella rupestris 170
Senecio, frigidus 297; lugens **Blaisdellii** 298; resedifolius 298.
Sequoia, morphology of 168; sempervirens 97, 159
Serratula *alpina* 297
Setouratea, 391
Seward, A. C., work of 389
Sexual cells, character of 167
Shaw, Charles H. 437; personal 320
Shear, C. L 220; personal 479
Shibata, K., work of 312, 471
Shull, G. H., personal 88, 319; work of 390
Sidalcea 316
Sieversia *Rossii* 203
Silene acaulis 140
Smith, Mrs. A. M., personal 320
Smith, Benjamin H., personal 86
Smith, Erwin F., personal 85, 398
Smith, John Donnell 249
Smith, Ralph E. 421
Smut, of oats 387; of onion 84
Snow, Laetitia M., personal 88
Solanum 77
Solidago multiradiata 299
Solutes, absorption and excretion of 393
Sophia 473
Sorophoreae 239
Spalding, V. M., personal 173, 319
Species, von Wettstein on origin of new 313
Sperms, character of 167
Sphaerostilbe microspora, conidiophores of 20
Spillman, W. J., personal 247, 319
Spiraea, betulaeflora 204; flower and embryo of 451
Spirogyra, mitosis in 315
Sporangia, imperfect in pteridophytes 473; with tracheal elements 389
Spores, in Taphrina 242; relations of light to germination 164
Spraguea 316
Stachys 316
Stahl, work of 77, 82
Stanleya 473
Starch, formation in Hydrodictyon, Timberlake on 314; Czapek on transformation to sugar 73

Statice *Armeria* 213
Statistical methods, Whitney on 312
Stellaria longipes 140
Stenadenium 78
Stephani, F., work of 77
Sterigmatocystis nigra and copper compounds 31
Stevens, W. C., work of 391
Stilbum vulgare 21
Stokes prize 398
Stoklasa, Julius, personal 247
Stomata, in winter 337
Strasburger, E., work of 79, 390; "Das kleine botanische Practicum" 310
Sturgis, W. C., work of 44
Subterranean organs of Liliaceae 401
Sugars, effect on Botrytis 428
Swartzia myrtifolia **Guatemalensis** 251
Symplocaceae 71
Synthesis, and anthocyan 82; and chlorophyll 82; of carbohydrate 83
Synthyris 473

T

Tannin, effect on Botrytis 429
Tansley, A. G., personal 248; work of 76
Taphrina, spore formation in 242
Taraxacum, Dens-leonis 299; officinale lividum 299.
Taubert, work of 391
Taubet, work of 384
Taxodium, morphology of 168
Taxus, baccata 97; male gametophyte of 91
Teodoresco, work of 81
Thalictrum, alpinum 144; purpurascens, parthenogenesis in 363
Thelypodium 473
Theriot, I., work of 315
Thom, Charles, personal 87
Thomas, A. P. W., work of 78, 392
Thomé, work of 385; "Flora von Deutschland" 71, 385
Thornber, J. J., personal 87
Tieghem. Ph. van, work of 391
Tilden, Josephine E., personal 85, 248
Tilia, **eburnea** 231; heterophylla 230, 231; pubescens 231
Timberlake, H. G., 80; personal 87; work of 314
Timpe, work of 76
Tofieldia, *borealis* 131; palustris 131
Tollens, work of 73
Townsend, C. O., 470
Toxicity of copper 26, 74
Tracy, S. M., personal 400.
Tradescantia, **Laramiensis** 68; scopulorum 68
Transpiration of evergreen trees, Kusamo on 313
Trees, American 230; new North American 108
Trelease, William, personal 86, 87, 172
Trema **enantiophylla** 259
Tremella mycetophila 4
Trientalis, *arctica* 213; arctica 212; Europaea 213
Trifolium 316
Trillium 473; ovatum, subterranean organs of 409
Triscyphus 384, 391
Trow, work of 314
True, R. H., personal 320
Tubercularia volutella, conidiophores of 20
Tubers, relation to fungi 75
Tubeuf, K. von, personal 319
Tucker, work of 73
Tussilago *frigida* 297

U

Uhlworm, O., personal 87
Umbach, L. M., personal 87
Underwood, L. M., work of 390
Urban, Ignatius, work of 384; "Symbolae Antillanae" 384
Uredineae 62
Uredo 473
Urnula 392
Uromyces 473
Uvariastrum 385.

V

Vaccinium uliginosum 211
Valeriana capitata 294
Variation, in relation to heterogenesis 396; of ray flowers of Compositae 462; quantitative study in Aster 390
Vegetation, influence of rocks on 316
Veronica alpina 292
Vines, S. H., personal 87; work of 313
Viola, biflora 207; palustris 207
Vladesco, personal 247

W

Wagner, Rudolf, work of 78
Ward, H. Marshall: "Disease in Plants" 466
Warming, Eugen., personal 85; work of 384; "Lehrbuch der ökologischen Pflanzengeographie" 399; "Podostemaceae" 71
Water, absorption and excretion of 393
Webb, J. E., 451
Webber, H. J., work of 395

Weber, work of 473
Wehmer, work of 73
Went, F. A. F. C., work of 243
West, W. and G. S., work of 78
Westgate, J. M., personal 88
Wettstein, von, personal 85; work of 313
Wheeler, C. F., personal 88
Whitford, H. N., 313, 316; personal 88, 247, 399, 480
Whitney, work of 313
Weisner, work of 386: "Die Rohstoffe des Pflanzenreiches" 386
Wilcox, E. M., 462; personal 88
Wilczek, E., work of 315
Williams, R. S., work of 316
Willis, J. C., personal 480
Willis, O. R., death of 479
Winkler, Hans, personal 247; work of 166
Winter, stomata in 337
Wolfe, J. J., personal 320
Woods Hole, botanical courses 320; morainal depressions of 437
Wright, Mabel Osgood: "Flowers and ferns in their haunts" 70
Wrightson, P. G., 393

Y

Yeast, a conjugating 72
Yendo, K., personal 248
Yocum, Georgia M., personal 88

Z

Zacharias, E., personal 399; work of 167
Zamia, Webber on 395
Zielstorff, work of 73
Zimmermann, A., personal 479; work of 240, 389.
Zostera marina, Rosenberg on pollen of 165
Zygadenus, elegans 131; Fremonti, subterranean organs of 411; *glaucus* 131
Zygosaccharomyces 73